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Future Naval Concepts — Crew Reductions through Improved Damage Control Communications (FNC-CRIDCC)

2006 Final Report

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14. ABSTRACT

The object of the Damage Control (DC) Triad program was to develop a Damage Control Communications system, which would be damage tolerant and remain operable in casualty situations where DC communications are vital. The current state of the art in communications technologies (WLAN, enhanced VoIP Power Line Communications, and Sound-Powered Phone implementations) should allow the implementation of the system without a costly R&D program. This report details the communications technologies and their application and testing in a shipboard environment to implement and demonstrate a true uninterruptible and survivable DC Communications system

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Damage control	Voice over Internet Protocol (VoIP)	Intelligibility standards
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CONTENTS

FUTURE NAVAL CONCEPTS-CREW REDUCTIONS THROUGH IMPROVED DAMAGE CONTROL COMMUNICATIONS (FNC-CRIDCC)

FY2006 FINAL REPORT

1.0 Introduction

Ships of the future will require vast, state-of-the-art, survivable communications networks capable of integrating a multitude of communications architectures with numerous communications sources and technologies. In order to maintain an operational DC communications capability during ship conflagrations and DC operations, a communication system must be diverse and have the capability of operationally monitoring communications capabilities and re-routing communications by automatically switching from the failed paths/technologies to ones that are still operational. Using a combination of wired and wireless technologies could allow damaged areas of the ship to communicate using one technology and the rest of the ship to use another technology. The DC Triad concept will provide data and voice using a combination of wireless LAN's and communication over a ships power grid and as a fallback option will provide a wireless voice link into a ship's sound powered phone circuits. Previous radio frequency (RF) communications system development and testing in condition ZEBRA environments onboard the ex-USS SHADWELL has determined the effectiveness of wireless LAN's used for communications in that environment. In addition, several public utility companies have installed, tested and are using equipment that delivers low cost DSL internet connections to their customers, over their power lines. The successful power line delivery of internet connections and the wireless development on ex-USS SHADWELL indicate that a state-of-the-art communication system using these technologies is possible for shipboard use. Three data delivery approaches will provide the capability for a survivable DC communications system. The three communications technologies are; (a) wireless local area networks (LAN), (b) power line communications and (c) a wireless input to the sound powered phone system. This effort has been designated Damage Control Operational Concepts Phase II.

MTS Technologies, Inc., under contract to the Office of Naval Research (ONR) through The Future Naval Capabilities—Crew Reductions through Improved Damage Control Communications (FNC-CRIDCC) Program, implemented a conceptual prototype Damage Control (DC) communications capability. The objective of the prototype is to provide a redundant, reconfigurable, recoverable, compatible (backward and forward) communications capability complementing and enhancing current DC capabilities. Commercially available equipment and capabilities was employed to implement a DC Triad prototype. The prototype includes; (a) wireless voice and data transmission over Wireless Local Area Network (WLAN) using Voice/Data over Internet Protocol (VoIP), (b) voice and data transmission over shipboard power lines (Power Line Communications - PLC) and (c) voice over Sound-Powered Phone (SPP) lines.

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The prototype is configured in the Damage Control (DC) "triad" communications concept discussed above, which at its core has a wireless communications interface between a DC decision-maker at the scene of an event and the DC command and control node. The prototype is intended to provide a redundant (i.e., multiple transmission paths), reconfigurable, recoverable (i.e., straightforwardly restore), compatible (backward and forward) capability that both complements and enhances the current core DC capabilities. This program implementation expands research completed during Phase II of the Damage Control Operational Concepts (DCOC) Program, conducted in FY05 [1] and documents the demonstration of the DC Triad prototype on ex-USS SHADWELL on September 18 – 22, 2006 [1].

1.1 Overview of the FNC-CRIDCC Project

The FNC-CRIDCC program continued the research work completed under Phase II of the Damage Control Operational Concepts (DCOC) Program completed in FY05 [1]. The DCOC Phase II Program researched and identified commercially available candidate equipments and capabilities that appeared suitable for wireless voice and data transmission over internet protocol (VoIP), voice (and data) transmission over shipboard power lines (using a ship's electrical distribution system) and voice over sound-powered telephone (SPP) lines (e.g., X40J, JA, etc.) [1].

1.2 General Approach to the Project

One of the more vital requirements of Damage Control is the ability to exchange information accurately and rapidly among on-scene repair leaders and the ship's Damage Control and Command and Control nodes. This allows decision-makers to understand the status of the ship, the progress of DC efforts, make reasonable allocations of DC resources, and assess the ability of the crew to continue to "fight the ship." Communications systems that provide significant enhancements in accuracy, speed of information flow, robustness, reliability, and redundancy are means to improve DC efficacy. In the reduced-manning environment projected for future Navy ship classes, Damage Control requires an increased capability to mechanically augment or automate actions taken by the ship's DC parties. To achieve the level of information flow required to accurately assess and respond to casualties, the Navy needs a DC communications capability that is robust, reliable, and state-of-the-art. That capability must have component and transmission route redundancy, be compatible with future as well as legacy systems, and require minimal intervention on the part of the shipboard DC team.

Casualty communications aboard Navy ships have not changed significantly in the last half-century. Newer ship classes have the same World War Two-vintage Sound Powered Phone (SPP) circuits as the backup casualty control communications path. While this is a proven system, it requires a great deal of human interface in normal operations and even more to restore casualties. Additionally, such legacy systems lack the necessary data flow rates, robustness, reliability, redundancy, and capability to maintain a comprehensive DC operational picture at all levels of command. Existing DC communication systems are, therefore, increasingly sub-optimal in "Smart Ship" and reduced manning environments. The Navy designed these "smart ships" to accommodate reduced manning, modular warfare suites, and the potential for rapid and frequent changes in assigned personnel. Future DC teams will no longer have the ability to compensate for communications shortfalls with additional personnel or to rely on the Damage Control Party's intimate familiarity with alternate communications paths or compartment layout gained through experience and from repetitive drills. The Naval Research Laboratory (NRL) designated a triad of communication technologies which when integrated into a system could survive shipboard casualties. This triad of communication technologies could provide an alternative to current casualty communications systems that will enable ships with reduced crew complements to maintain critical casualty control capabilities. This proof-of-concept prototype explores whether these capabilities can be achieved by embracing current and emerging technologies and the enhanced capabilities they offer.

1.3 Development of a Communications Concept

The Naval Research Laboratory developed a survivable damage control communications concept comprised of three communications paths, called DC Triad. Each of the three communications paths uses a different communication technology. Communications are automatically rerouted when the initial path is interrupted or destroyed. This communication concept provides survivability, improved communications and workforce reduction by lessening the command and control workload through enhanced data throughput. The Office of Naval Research (ONR) and the Naval Research Laboratory's Chemistry Division in conjunction with MTS Technologies, Inc. developed and implemented a DC Triad system prototype. Developmental efforts leveraged available commercial technologies that employed combinations of wireless voice and data technologies in a cooperative environment. Selection criteria included compatibility with Navy shipboard environments and were operationally tested on the Navy's Damage Control R&D platform, the ex-USS *Shadwell* in Mobile, Alabama [3]. The primary goal of the development effort was a redundant, reconfigurable, multi-path communications capability to ensure exchange of information among key personnel involved in damage control efforts aboard ship.

The prototype concept identified three distinct paths for communications among On-Scene Leaders (OSLs), Repair Lockers, and Damage Control Central (DCC):

- Voice and data over Internet protocol (hereafter called VoIP) using a Wireless Local Area Network (WLAN)
- Voice and data transmission over shipboard electrical power distribution system using Power Line Communications (PLC) technologies

- Wireless voice interface with the ship's sound powered phone circuit using Voice Over WiFi technologies as part of the wireless design

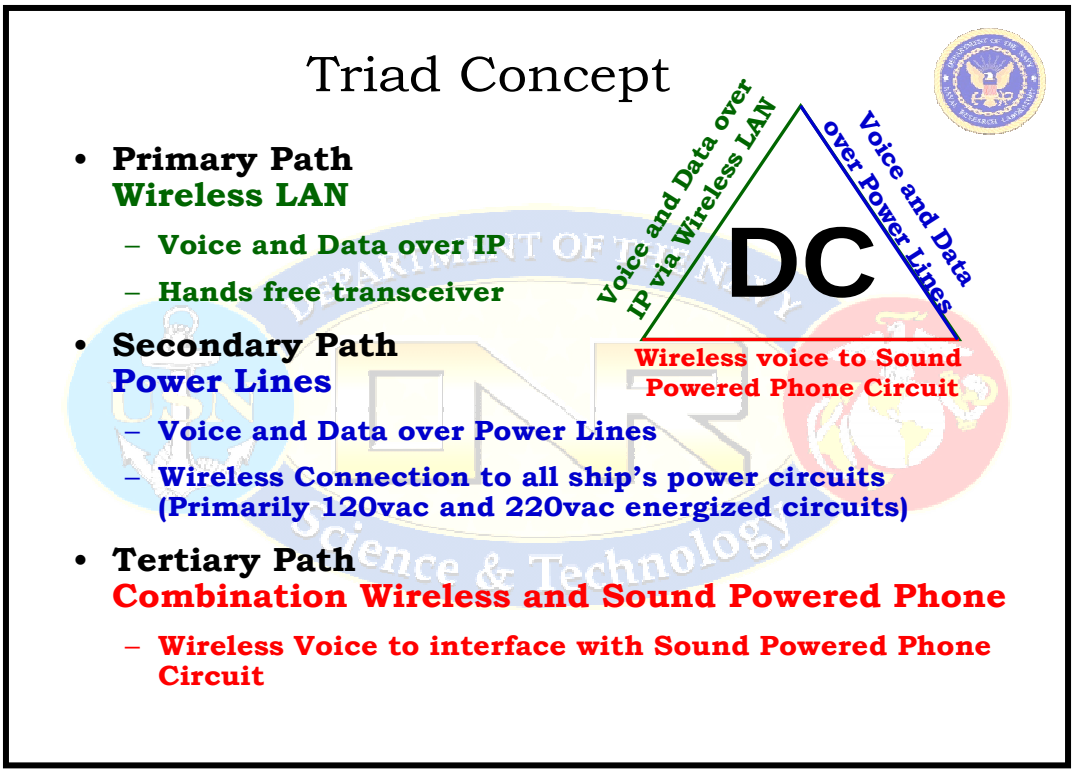

Figure 1 – The "Triad" Communications Concept

A multi-path communications prototype was developed, tested, and evaluated to demonstrate possible enhancements to casualty communications aboard Navy ships [4][5]. The prototype features commercially available technologies, combined in new ways to provide redundant, reconfigurable multi-path communications among On-Scene Leaders, repair lockers, and Damage Control Central. The prototype complements and enhances current casualty control systems. The preliminary Triad capability architecture consists of:

- An On Scene Leader communications device to transmit voice and data
- A portable Wireless Access Point to enable voice and data over Internet Protocol
- A Power Line Communication device to enable voice and data transmission using the ship's power grid
- An audio coupler to provide wireless, full-duplex analog voice capability between the On Scene Leader and Repair Lockers or DC Central, via the existing SPP circuits.

This new proof-of-concept DC communications system uses three main resources:

- A LAN backbone which supports VoIP which is deployed and covers portions of five (5) decks on ex-USS *Shadwell* [6][7][8].
- Voice and data over the ship's wired electrical power distribution circuits.
- A wireless connection into the ship's sound powered phone (SPP) circuits.

Improved communications capabilities enhance emergency response, particularly on ships with reduced crew levels, such as LPD-17, LCS, and DDG-1000.

2.0 Objectives

2.1 Introduction

The overall objective of the Program was to develop a proof-of-concept prototype Damage Control communications capability. This was a research, development, test, and evaluation (RDT&E) project to design and develop a working prototype to prove the concept that a multi-path casualty communications system is viable for use in the shipboard environment. The working prototype was to demonstrate a reconfigurable, redundant, multi-path communications capability to facilitate reductions in crew levels while enhancing voice and data communications among personnel engaged in damage control efforts aboard ship.

2.2 Scope

The scope of this project was to research commercially available technology. Develop and test a prototype to measure communications improvements achievable in lieu of additional personnel on damage control teams. It was the intent of this project to further damage control concepts, engineering initiatives, operational concepts, architectures, and technologies that hold potential for improved voice and data transmissions during damage control operations. The proof-of-concept was to demonstrate that the working prototype was capable of transmitting:

- Voice and data using VoIP technology over a WLAN
- Voice and data using Power line Communications (PLC) technology
- Wireless voice to sound powered phone circuits.

Engineers and analysts conducted basic and applied research including operations analysis, interoperability analysis, technology assessment, and experimentation planning to guide this effort. The following criteria was used to define the research and prototyping effort:

- Candidate technology components for voice and data transmissions are operational and commercially available for evaluation and integration into the prototype Triad capability [1]

- Wireless LAN path VoIP candidates that support both voice and data transmission [1]
- PLC path candidates that support both voice and data transmission and enable transmission across multiple voltage circuits similar to those found throughout active ships of the fleet [1]

2.3 Project Objectives

The project objectives include:

- Develop a prototype communications capability that has the following attributes:
- Redundant using multiple transmission paths
- Reconfigurable through software path monitoring
- Recoverable or easily restored with minimal crew intervention
- Backward and forward compatible – adaptable to current fleet ships and capable of integration into future ship designs
- Complements current core DC capabilities and provide additional capabilities.
- Test each path of the "Triad" communications prototype and integrate the separate paths into shipboard systems.
- Design and develop interfaces that permit transmission of wireless information through multiple shipboard paths. Candidate technologies were evaluated aboard the ex-USS *Shadwell* to determine shipboard performance characteristics and identify interoperability issues [4][5].
- Demonstrate the ability of a prototype multi-path casualty communications capability to operate successfully in ex-USS *Shadwell* for ongoing operational tests and demonstrations by ONR/NRL [4][5].
- Design and develop new equipment (not commercially available) to convert a wireless voice signal to an analog signal compatible with the Sound-Powered Phone circuit.

Specific objectives include:

- Demonstrate the ability of individual communications equipment to operate within established parameters
- Demonstrate the ability of individual communications equipment to operate together as part of a prototype capability

- Demonstrate in the Navy's Fire Test Laboratory, ex-USS *Shadwell*, the ability of a prototype DC Communications system to operate in its projected operating environment.
- Evaluate differing configurations within the prototype capability
- Validate the Trade Space established as part of the Damage Control Operational Concepts (DCOC) Phase II Project [2][4][5].

3.0 Testing

3.1 VoIP/PLC Fire Event Test Team

The VoIP/PLC Fire Event Test Team was responsible for the test and evaluation of the prototype configuration for the DC Communications Triad Concept under actual fire and smoke conditions. The Team gathered empirical data on effects of fire and smoke as related to the ex-USS Shadwell wireless LAN and tested voice communications between a simulated fire team On Scene Leader in a controlled fire and smoke environment and another individual in a separate location. The VoIP/PLC Fire Event Test Team consisted of MTS analysts and engineers and designated ex-USS Shadwell personnel. They were task-organized into teams to conduct an "Objective VoIP Wireless Fire Test" and a "Subjective VoIP Call Evaluation" in order to accomplish these goals. Arthur Durkin (NRL), the Fire Event Team Leader, maintained overall responsibility for initiating all fire tests and conducting voice communications with the fire test coordinators. He was supported by Hung Phan (NRL); MTS PM, Scott Cooper; and MTS engineer, Shawn Nocita. Kenny McCombs and Michael Hammers were the MTS VoIP Fire Test Coordinators, assisted by Petty Officer Gunn, a Navy Reservist on his ACDUTRA assignment to the ex-USS Shadwell ship support staff. The VoIP Fire Test Teams maintained open lines of communication with the fire test coordinators and recorded and saved data points during the fire tests. Fire Test Team #1 was comprised of *MTS* engineer Chuck Miller and L. Robert Kimball & Associates engineer David Showalter. Fire Test Team #2 was comprised of *MTS* engineers Michael Rininger and Brad Shirley, assisted by Petty Officer Ramsey, a Navy Reservist on his ACDUTRA assignment to the ex-USS *Shadwell* ship support staff.

4.0 Prototype Development

4.1 Laboratory Facilities

During the initial phase of the program, the Prototype Development Integrated Program Team (IPT) procured candidate equipment and capabilities for testing. The initial test series evaluated candidate equipments and technologies that comprised the DC communications triad in a shore-based laboratory facility [4]. The Prototype Development IPT tested the interoperability and overall performance of various components to develop a prototype that embodied performance objectives identified during the DCOC Phase II Program [4][5].

Initial data collection focused on the existing WLAN capability, LAN backbone, the electrical AC power grid, and SPP functionality. These considerations were driving factors in the design of the laboratory network architectures to accommodate developing and testing the VoIP, PLC, and SPP Triad pathways.

Three transmission pathways in the DC Communications Triad concept require testing; communications engineers set up each path separately. They configured components to achieve optimal performance for each pathway as a first step in determining feasibility and adaptability. Limited and full-scale operational tests of equipment and configurations achieved initial feasibility and adaptability determinations in the communications laboratory [4].

To accommodate PLC Triad path development, a PLC Telkonet® iBridge was mounted adjacent to the sub-panel along with a PLC Gateway. For safety considerations, an emergency interlock with a highly visible actuator was placed at a location removed from the distribution panel and the four 208 Volts AC outlets, (two circuit branches, with two outlets each). An existing audio R&D laboratory area was made available where electrically non-conductive workbench units were installed, along with lockable storage cabinets, parts storage bins, illuminated magnifiers, AC power outlet multipliers, electrical and electronic test and measurement equipment, anti-static mats, LAN drops, and tools to support initial FNC-CRIDCC tasks. When completed, the communications laboratory consisted of:

- A wireless LAN emulating that found in the ex-USS *Shadwell* to facilitate wireless voice and data transmission interface with the ex-USS *Shadwell*'s LAN backbone
- A MIL-STD-1399-300A electrical power grid providing 208 Volts AC to facilitate test and evaluation of candidate technology performance in the area of voice and data transmission over shipboard power lines
- A sound powered phone (SPP) circuit including wiring, plugs, switches, handsets and headsets to facilitate engineering design and development of a wireless interface to the ship's SPP circuit.

4.2 Preliminary Research and Development

The first step involved a thorough market survey by the Analysis IPT for candidate components and equipment to gather specifications and document performance data before further testing by the Prototype Development IPT [1]. Candidate components and equipment were tested and evaluated according to manufacturer's specifications. Specifications obtained from manufacturers served as baseline measurements for individual component and equipment performance.

Next was detailed evaluation and analysis of performance specifications of each component compared to the target performance required by the system and other components in the same category. Engineers compared hypothetical performance specifications supplied by manufacturers with actual, calibrated measurements obtained while the equipment operated in the laboratory environment [4]. Candidate components that met or exceeded pre-established criteria were designated for further testing as part of a complete capability representative of the prototype DC Communications Triad.

Capability configurations were demonstrated and evaluated for interoperability and a capacity to provide the required communications capability. Engineers constructed and tested different equipment configurations to determine which configuration would perform best in the operational test environment.

The selection of software went through the same process: initial market survey, candidate selection, and evaluation of selected packages. A number of factors were considered in selection of software for the system. Past experience, robustness, and maintainability were key criteria for inclusion. Open source and standards-based protocols were also assigned a high priority in order to provide better interoperability and expandability in future projects [4].

Research conducted as part of the overall DCOC Phase II Project provided the basis for the following criteria used by the Analysis and Prototype Development IPTs:

- The candidate capability configurations are portable.
- The Triad communication capability is based on commercially available products. Prototype components need not meet MILSPEC requirements; however, the Prototype Development IPT will consider available MIL-SPEC rated components if they meet performance requirements. The goal is to prove the Triad concept using components that function in the specific environment in which they are installed or used, regardless of whether or not they meet a particular standard.
- The front-end components used by the On-Scene Leader (OSL) will be subjected to more environmental stress than components located in Repair Lockers or DC Central, although, it is assumed that the OSL maintains some distance from the extreme high heat and water exposure.
- The candidate capability configurations will be subject to Electro-Magnetic Interference (EMI) in the operational environment, but such susceptibility must still allow for nominal operation of the Triad.

Because of Hurricane Katrina, the ex-USS *Shadwell* was unavailable for onboard testing much of calendar year 2006. This resulted in insufficient opportunities to test the prototype with the major source of EMI, the medium pressure water mist pumps, online. Since ex-USS *Shadwell* operates neither radar nor RF radio communication systems, there was no opportunity to explore additional EMI effects.

4.3 Component Selection and Evaluation

4.3.1 Powerline Communications (PLC)

In order to investigate the feasibility of developing a PLC network in ex-USS *Shadwell*, products were obtained and evaluated. The desired system would support voice and data communications over the existing ex-USS *Shadwell* AC electrical wiring. This would potentially provide an instant communications network with every AC outlet becoming a potential LAN drop. Manufacturers investigated included Linksys®, Telkonet®, Yamar®, and Maxim/ Dallas®.

The project focus was the ex-USS *Shadwell.* Several requirements of the PLC system were identified as follows:

- Compatible with both 115 VAC and 208 VAC systems
- In-Building PLC (IBPLC) as opposed to Broadband over Power Line (BPL), which uses electrical distribution lines on poles or underground to provide broadband access over the power grid
- COTS ready
- High data rate
- Reliable
- High temp rating
- Rugged
- Secure
- Scalability/expandability

Two of the manufacturers considered were eliminated early. Yamar® was not purchased because the components are designed for Automotive DC systems instead of AC Systems. Maxim/ Dallas® was considered but did not provide a commercially available product suitable for integration. The Prototype Development IPT purchased Linksys® and Telkonet® PLC products for evaluation.

4.3.1.1 Linksys®

Although Linksys® components did not meet the 208 VAC condition, it was purchased for evaluation because of its low cost and simplicity, and most AC outlets aboard ex-USS *Shadwell* are 115 VAC. Some Linksys® specifications include:

- Designed for in-home use

- Designed to the HomePlug 1.0 standard
- Powerline speed specification: Up to 14 Mbps (Powerline USB Adaptor limited to 12 Mbps)
- Encryption 56-bit WEP Data Encryption with Key Management
- LED indications for Powerline – Activity, Link, Collision
- LED indications for Ethernet – Link, 100, Activity
- Operating Temperature : 32ºF-104ºF (0ºC-40ºC)
- Operating Humidity : 10% to 85% Non-Condensing
- No information on scalability was available

The Prototype Development IPT installed the Linksys® Powerline USB Adapter and EtherFast 10/100 Bridge components in the lab. Using these devices, it was possible to communicate between two computers on the PLC network. Stability of the Linksys® network was low. The connection speed was variable over the same outlets and typically ranged from 0.9 Mbps to 3 Mbps. A password is required to communicate with another device. No configuration software utility was included with this system. Because of the unstable characteristics, low data rate, minimal security features (i.e., 56-bit Wired Equivalent Privacy (WEP) encryption capability vice 64 or 128-bit WEP encryption or WiFi Protected Access (WPA) 1 or 2) and unsuitable power and environmental specifications, it was not considered for further testing in ex-USS *Shadwell*.

4.3.1.2 Telkonet®

The Prototype Development IPT installed the Telkonet® components in the lab and tested the system over the 115 VAC and the 208 VAC outlets. The system worked consistently and reliably. Some of the specifications of the Telkonet® system include:

- Designed for industrial use and Enterprise network support
- Designed to the Telkonet® Plugplus System, which is an improved HomePlug Solution
- Designed to protect the transmitted signals over the power line from most noise interference, such as brush motors, fluorescent and halogen lamps, switching power supplies, dimmer switches, and amateur band radio transmitters.
- Telkonet's® PLC System uses Orthogonal Frequency Division Multiplexing (OFDM) to ensure continuous network traffic with minimal bandwidth impact.
- The PLC chipset used occupies the band from 4.5 to 21 MHz

- Adaptive physical layer adjusts to varying channel conditions with speeds up to 14 Mbps
- Network layer speeds in excess of 7 Mbps (rate varies based on channel conditions)
- Over the band, Telkonet® software filters control the power spectral density (PSD) of the signal, and apply 30 dB notches required to avoid interference with low frequency sources such as amateur radio operators.
- Web-based management software to configure the system
- 256-bit AES Security
- Federal Information Processing Standards (FIPS)140-2 Certified Components
- Telkonet® Gateway® acts as a remotely manageable network switch that converts data between a 10/100 Ethernet Port and a PLC interface. Each Gateway supports up to 63 eXtenders®, 512 iBridges® and 4096 Ethernet endpoints
- Telkonet® iBridge® act as an intelligent, single port Ethernet to PLC device converting an AC outlet to a LAN drop. Each iBridge® communicates with the Telkonet® Gateway and/or eXtender® using AES 256-bit encrypted data stream.
- Telkonet® eXtender® provides additional reach and scalability for network environments that cannot be properly covered by a single Gateway.
- Telkonet® Coupler® is a passive device through which the Gateway or eXtender® injects the PLC signal into the AC Power infrastructure.
- Operational Temperature for all components: 32 deg F to 122 deg F (0 deg C to 5 deg C)
- Small size and weight components
- Power/Input Rating for eXtender®, Gateway, and iBridge® : 100-240 VAC, 0.25 amps
- Power/Input Rating for Coupler : 100-480 VAC, 0.1 amps, 50/60 Hz, AC-3AC, Wye and Delta
- LED indication lights depicting the status of Power, PLC Link/Activity and Ethernet Link/Activity

The Telkonet® system surpassed the Linksys® system in all respects; including power specifications, environmental specifications, security, and performance. The Telkonet® system was chosen for ex-USS *Shadwell* installation.

4.3.1.3 Access Points for Powerline Communications

Access points were investigated in order to provide a wireless interface to the PLC network and integrate PLC communications with VoIP over WLAN communications. In this way, a call can be automatically transitioned from talking over an Access Point connected to the PLC network to an Access Point installed on the ship's WLAN.

The selection process for determining which access point will be use in the design of the prototype was based primarily upon the vendor specifications. The specifications for the access points that were evaluated are listed in the matrix below. The following access points were investigated for their potential application:

Table 1 – Matrix of Vendor Access Point Specifications

Device	Model #	Technology	Operating Temp.	Tx Power	Security
Linksys® Wireless-G Access Point w/SRX	WAP54GX	802.11b/g	0˚-60˚ C	20dBm(802.11b) 14dBm(802.11g)	WEP,AES, TKIP,802.11i
Linksys® Wireless G Access Point	WAP54G	802.11b/g	0˚-40˚ C	16.5dBm ± 2dBm (802.11b) 13.5dBm ± 2dBm (802.11g)	WPA, WEP
ASUS® Pocket 4-port Router	WL-530G	802.11b/g	0˚-40˚ C	12-15dBm	WEP, WPA, WPA2
D-Link® Wireless 108G QoS Router	DI-724U	802.11b/g	0˚-55˚ C	15dBm ± 2 dBm	WPA, WEP
SMC® Wireless Broadband Router 802.11g	SMCWBR14-G	802.11b/g	0˚-40˚ C	12-15dBm	WEP, AES
SMC® Travel Router	SMCWTK-G	802.11b/g	0˚-55˚ C	15-18dBm	WEP, WPA
3COM®	3CRGPOE10075	802.11a/b/g	0˚-40˚ C	18dBm	Open, Shared, WPA, WPA
Proxim®	AP-4000	802.11a/b/g	0˚-55˚ C	18-20dBm	802.11i, AES, WEP
US Robotics®	USR5451	802.11b/g			WEP, WPA, WPA2

After reviewing options available for AP selections, the Proxim® AP-4000 presented itself as the best choice for the prototype based upon vendor specifications and alternative features that can be used in conjunction with existing ex-USS *Shadwell* Proxim® AP-2000 access points. The Proxim® AP-4000 is a small AP that fits securely in the lid of the prototype Comm Case and uses tri-mode 802.11 standards.

4.3.2 Voice over Internet Protocol (VoIP)

4.3.2.1 VoIP System Solutions

The VoIP path of the Triad concept required a combination of hardware and software to support end-to-end communications. A VoIP solution is a system that contains components necessary for VoIP communication such as a communications server with capabilities of handling call control between VoIP endpoints. These systems also can provide telephony PBX (Private Branch Exchange) functions such as extension dialing, conference calling, call forwarding, and voicemail. An extensive market survey was done of VoIP Server Systems with the following criteria used as evaluation guidelines:

- Fully SIP (Session Initiation Protocol) compliant
- Browser-based administrative Graphic User Interface (GUI)
- "User friendly" administrative GUI
- Ability to interface to other communications systems as necessary
- Ability to support a variety of "endpoints" – wireless IP phones, wired IP phones, Softphones
- Robustness
- Reliability
- Cost-effective; good price point
- Scalable
- Text messaging support
- Security features
- Small physical size/footprint/weight
- Simple non-complex architecture

The following systems were selected for purchase and evaluated:

- Vocera® Communications
- Zultys® MX-250
- Pingtel® SIPxchange

4.3.2.1.1 Vocera® Communications

Although the Vocera® system did not meet some of the criteria (namely, SIP compliance and text messaging support), it was purchased because of its unique features:

- All-in-one solution. The Vocera® system comes with its own unique endpoints: Vocera® Communications Badges.
- The communications badges are considerably smaller and lighter than other endpoints evaluated
- Hands-free interface – calls are initiated through a push button and speech recognition, not by interacting with a dial pad.
- Speech recognition feature
- Potential to provide redundancy or a complementary system to a more "standard" SIP VoIP system

The Prototype Development IPT installed the Vocera® Server and Telephony Server software along with supporting administrative console software packages on a Dell® Poweredge® 1800 server in the laboratory. Six Vocera® communications badges were initialized and configured. The LAN in the laboratory was used as the network infrastructure. Engineers performed evaluations by communicating with each other using the Vocera® badges. Initial configuration was somewhat cumbersome because the badges are hard-coded to look for certain server IP address in order to download their configuration information.

The Vocera® Administration Console software provides an easy to use browser-based interface for configuring the system's users, groups, and other parameters. The badges are easy to use and have a number of options for calling other badges (call direct, urgent call, broadcast to group, panic call, and push-to-talk mode). The badges are extremely small and lightweight, but not rugged.

Audio quality on the badges is acceptable for volume capability when used with a headset to ensure better speech recognition and reduce potential negative ambient noise effects. Battery life is dependent upon the amount of badge utilization, and must be monitored.

Speech recognition can be very helpful in a low-noise environment, but it is challenging to get the Vocera® system to recognize voice commands in a high-noise environment. For optimal performance, each user needs to train the badge to recognize his own voice because of unique tone, inflection, and accent of each person's voice. This could be a hindrance in a time-critical situation or when replacing a damaged badge with a spare.

In addition to volume control, buttons on the side of the badge provide a method of accessing various kinds of data, such as wireless access point information. These buttons are relatively tiny and can be difficult to use, especially with gloved hands.

In the laboratory, engineers integrated the Vocera® system with the Zultys® MX-250 through analog trunking utilizing an Intel Dialogic interface board and a Zultys® FXS interface board. The integration allowed for the successful completion of calls in both directions between Vocera® badges and various endpoints on the Zultys® MX-250 system.

The Vocera® Communications system was chosen as a complementary VoIP system for the Triad prototype. It is recommended for use as a "back channel" communications system and not as the direct means of communication between the On Scene Leader and Repair Locker.

4.3.2.1.2 Zultys® MX-250

The Zultys® MX-250 was installed and configured in the laboratory and tested with a number of endpoints. Engineers performed evaluations by communicating with each other using various SIP endpoints. Endpoints were configured as phone extensions on the MX-250, allowing for 3-digit dialing. The MX-250 is a single-box turnkey solution with a small physical footprint that has an excellent intuitive browser-based administrator interface that allowed for ease of configuration. Many SIP endpoints were successfully used on the MX-250, including the Zultys® ZIP® family of wired IP phones and wireless devices including the Zultys® WIP2®, the Hitachi® IP5000, the Symbol® MC50 and MC70, the iMate® JasJar, the Eten® M600, the Linksys® WIP330, and the Vocera® communications badges. Engineers also used desktop computers, laptop computers, and tablet computers as endpoints by running Softphone® software.

The MX-250 was selected as the main VoIP system for the Triad prototype because of its characteristics (good price point, fully SIP compliant, easily interfaced to other systems, excellent administrator interface, ease of configuration) and its reliability and observed robustness.

4.3.2.1.3 Pingtel® SIPxchange

The Pingtel® SIPxchange server was installed and configured in the laboratory and tested with a number of endpoints. Engineers performed evaluations by communicating with each other using various SIP endpoints configured as phone extensions on the SIPxchange to allow for 3-digit dialing. A number of SIP endpoints were successfully used on the SIPxchange, including the Polycom® family of wired IP phones and several wireless devices, including the Hitachi®IP5000 and the Symbol MC50, and desktop computers running Softphone software.

The footprint of the SIPxchange server was much larger than the Zultys® MX-250, and the user interface was not as intuitive or user friendly as the MX-250. The SIPxchange server was not as robust as the MX-250 in terms of "power up and go" functionality. In addition, the Linux operating system was "hidden" from the user – in order to use the browser-based administrative interface, you have to first login to Linux and then navigate to the SIPxchange browser.

Because of these issues and the engineers not having the opportunity to test the SIPxchange in ex-USS *Shadwell*, the SIPxchange system was not recommended for the initial Triad prototype.

4.3.2.2 SIP Wireless Phones

A SIP wireless phone is designed to communicate wirelessly using the SIP protocol. SIP wireless phones were under consideration as a potential communications device for the On Scene Leader. The requirement entailed the On Scene Leader to be untethered and mobile to move throughout the ship while communicating to a Repair Locker or DC Central. The wireless SIP phones must be 802.11b or 802.11g compliant in order to be compatible with the wireless LAN in ex-USS *Shadwell*.

There are not many SIP wireless phones in the evaluation. However, all SIP phones purchased were introduced as new products during the project timeframe. An exhaustive market survey was done of SIP wireless phones with the following criteria used as evaluation guidelines.

- Fully SIP (Session Initiation Protocol) compliant
- 802.11b or 802.11g
- Good audio quality
- Headset-capable
- Robust
- Reliable
- Cost-effective; good price point
- Text messaging support
- Security features
- Small physical size/footprint

The following SIP wireless phones were selected for purchase and evaluated:

- Hitachi®IP-5000
- Zultys® WIP2
- Linksys® WIP330

4.3.2.2.1 Hitachi® IP-5000

The Hitachi® IP-5000 was configured as an extension on both the Zultys® MX-250 and the Pingtel® SIPxchange systems and then tested in the laboratory. Engineers were able to make calls to and from other SIP endpoints using the IP-5000. The Hitachi® IP-5000 is an 802.11b wireless SIP phone that does not support 802.11g.

The IP-5000 provided good audio quality, with or without the use of a headset. However, a headset is recommended to reduce the potential negative effects of ambient noise effects. The relative small size and light weight of the IP-5000 make it very easily carried and used. The IP-5000 does support text messaging, although it is not compatible with the text messaging used on the project (Jabber® text messaging).

Battery life was better than most devices tested. The keypad provides good tactile feedback, and the keys cannot be easily depressed inadvertently. The display is simple and adequate and the menu system is adequate. One of the two IP-5000 phones purchased "died" after several months of periodic usage, and engineers were unable to get it powered back up and useful.

Although the IP-5000 has many good features, selection as a component of the FNC Triad prototype was precluded by its incompatibility with the Jabber® text messaging software and reliability questions raised by the malfunction of one of the two units.

4.3.2.2.2 Zultys® WIP2

The WIP2 was configured as an extension on the Zultys® MX-250 and was tested in the laboratory. Engineers were able to make calls to and from other SIP endpoints using the WIP2. The WIP2 is an 802.11b wireless SIP phone. It does not support 802.11g.

The WIP2 provided adequate audio quality. It does not have a standard 2.5mm headset jack like the majority of its counterparts. The Zultys® WIP2 phone is larger and heavier than its SIP wireless phone counterparts are. It is not easily carried in a pocket due to its thickness.

The WIP2 does support text messaging, although it is not compatible with the text messaging used on the project (Jabber® text messaging). It uses a proprietary Zultys® text messaging protocol, so it cannot exchange text messages with other vendors' devices. The WIP2's keypad provides adequate tactile feedback, and the keys protrude and so they can be easily depressed inadvertently. The display is simple and adequate and the menu system is adequate.

The WIP2 was not selected as a SIP wireless phone for the Triad prototype for all of the reasons stated above.

4.3.2.2.3 Linksys® WIP330

The WIP330 was configured as an extension on the Zultys® MX-250 and was tested in the laboratory. Engineers were able to make calls to and from other SIP endpoints using the WIP330. The WIP330 supports 802.11b and 802.11g. It provided adequate audio quality. It has a standard 2.5mm headset. The WIP330 is fairly small and light and is easily carried. The WIP330 does not support text messaging. The WIP2's keypad provides adequate tactile feedback. The WIP330 runs Windows CE, has a high-resolution color LCD screen, and provides some advanced functionality like web browsing and receiving live video.

Although the WIP330 is unique in its class because of its operating system and user interface, it was not selected as a component for the Triad prototype because of its lack of text messaging capability.

4.3.2.3 Wireless Enabled PDAs

Wireless enabled Personal Data Assistants (PDAs) were under consideration as a potential communications device for the On Scene Leader. The On Scene Leader is required to be untethered and mobile to permit movement throughout the ship while communicating with a Repair Locker or DC Central. Many handheld computers on the market are larger and heavier than what is practical for an On Scene Leader to carry.

There are many PDAs on the market, but very few have both integrated WiFi (802.11a, 802.11b, 802.11g) capability and high quality audio with built-in headset jack and microphone. An exhaustive market survey was done of wireless enabled PDAs with the following criteria used as evaluation guidelines.

- 802.11b or 802.11g
- Good Audio Quality
- Headset-Ready
- Robust
- Reliable
- Semi-hardened
- Cost-effective; good price point
- Small physical size/footprint
- VoIP Ready
- Wireless LAN utilities
- Bluetooth® desirable for evaluation but not a necessity

The following wireless enabled PDAs were selected for purchase and evaluated:

- Symbol® MC50
- Symbol® MC70
- Amrel® Rocky Patriot DA4-M
- Eten® M600
- iMate® JasJar

4.3.2.3.1 Symbol® MC50

The Symbol MC50 was configured as an extension on both the Zultys® MX-250 and the Pingtel® SIPxchange systems, and was tested in the laboratory. Engineers were able to make calls to and from other SIP endpoints using the MC50. The MC50 provided very good audio quality, with or without the use of a headset. However, a headset is recommended to reduce potential negative ambient noise effects. The MC50 has a standard 2.5mm headset jack and a built-in microphone. The MC50 supports only 802.11b, but has good wireless range. It has relatively small size and light weight, and is easily carried in a pocket. The MC50 is a semi-hardened device.

The MC50 runs the PocketPC® operating system and supports applications that run on that operating system. Several Softphone programs (see software section) were downloaded and utilized on the MC50. A text messaging client application (iMov® Messenger) was also downloaded and used successfully on the MC50.

Two version of the MC50 were purchased, one with a full QWERTY keypad, and one with a smaller, minimal (called NAV) keypad. The keypad provides good tactile feedback, and the keys cannot inadvertently be easily depressed. However, the touch screen on the MC50 can be touched and disturbed if the user is not careful.

Several times, one of the MC50's would lose its programs and resort to factory default condition when left unattended for an extended period. It appears that the best practice is to leave the MC50 on the charger, drawing power, to avoid this situation.

Overall, the MC50 is a very good wireless enabled PDA. Its size and functionality meet the requirements. It could have easily been selected as the On Scene Leader device for the FNC Triad prototype. The only reason it was not selected is that Symbol® came out with a "next generation" product called the MC70. The MC50 would be a very good backup On Scene Leader device choice.

4.3.2.3.2 Symbol MC70

The MC70 provided excellent audio quality, with or without the use of a headset. However, a headset is recommended to reduce potential negative effects of ambient noise. The MC70 has a standard 2.5mm headset jack and a built-in microphone. Its audio seems to be a bit "hotter"/louder than even the MC50. The MC70 supports 802.11a, 802.11b, and 802.11g, and has good wireless range. It is larger than the MC50, but is still relatively small size and light weight, and is easily carried in a pocket. The MC70 is a semi-hardened device, a little more rugged than the MC50 in its design. The MC70 supports Bluetooth®.

The MC70 runs the Windows® Mobile operating system and supports applications that run on that operating system. Several Softphone programs (see software section) were downloaded and utilized on the MC70. The Symbol® MC70 was configured as an extension on the Zultys® MX-250, and was tested in the lab. Engineers were able to make calls to and from other SIP endpoints using the MC70. A text messaging client application (iMov® Messenger) was also downloaded and used successfully on the MC70 to exchange text messages with other endpoints.

A version of the MC70 with a smaller, minimal keypad was purchased. The keypad provides good tactile feedback, and the keys cannot inadvertently be easily depressed. However, the touch screen on the MC70 can be touched and disturbed if the user is not careful.

Several times, one of the MC70s would lose its programs and resort to factory default condition when left unattended for an extended period. It appears that the best practice is to leave the MC70 on the charger, drawing power, to avoid this situation.

Overall, the MC70 is an excellent wireless enabled PDA. Its size and functionality both meet FNC requirements. It was selected as the On Scene Leader device for the FNC Triad prototype.

4.3.2.3.3 Amrel® Rocky Patriot DA4-M

The Amrel Rocky Patriot DA4-M is a rugged PDA designed for military applications. The first DA4-M that *MTS* purchased "locked up" frequently and was deemed defective and returned to the manufacturer. A replacement DA4-M was received a short time later. The DA4-M provided inadequate and unacceptable audio quality, with or without the use of a headset. The volume output is simply too low to allow for appropriate voice conversations under anticipated conditions.

Due to the very poor audio quality and doubts due to the lock up of the first DA4-M shipped, the Amrel® DA4-M was not selected.

4.3.2.3.4 Eten® M600

The Eten® M600 provided adequate audio quality, with or without the use of a headset. A headset is recommended to reduce potential negative effects of ambient noise. The M600 supports 802.11b only. The M600 has a built-in 1.3 Mega pixel camera and it supports Bluetooth®. It is the smallest of the PDAs evaluated and is easily carried in a pocket. The M600 is not hardened and is intended more for use as a cell phone/office PDA than for more rigorous use.

The M600 runs the Windows® Mobile operating system and supports applications that run on that operating system. Several Softphone programs (see software section) were downloaded on the M600. The M600 was configured as an extension on the Zultys® MX-250, and was tested in the lab. Engineers were unable to make calls to and from other SIP endpoints using the M600 because the preferred Softphone application (SJ Labs® SJPhone® – see software section) did not work properly on the M600. However, a text messaging client application (iMov® Messenger) was downloaded and used on the M600 to exchange text messages with other endpoints.

Because of the non-hardened nature of the M600, and because the preferred Softphone did not work properly on the M600, it was not selected as a component for the Triad prototype.

4.3.2.3.5 iMate® JasJar

The iMate® JasJar provided good audio quality, with or without the use of a headset. However, a headset is recommended to reduce potential negative ambient noise effects. The JasJar has a standard 2.5mm headset jack and a built-in microphone. The JasJar supports 802.11b only. It is larger than the Eten® M600 but smaller than the other PDAs that were purchased. The JasJar is easily carried in a pocket. The JasJar is a non-hardened device, intended mainly as an office PDA or smart phone.

The JasJar runs the Windows® Mobile operating system and supports applications that run on that operating system. Several Softphone programs (see software section) were downloaded and utilized on the JasJar. The JasJar was configured as an extension on the Zultys® MX-250, and was tested in the lab. Engineers were able to make calls to and from other SIP endpoints using the JasJar. A text messaging client application (iMov® Messenger) was also downloaded and used successfully on the JasJar to exchange text messages with other endpoints.

The JasJar has a full keyboard and a 180-degree pivot display screen/cover. The JasJar also has a built-in 1.3 Mega pixel camera. The keypad provides good tactile feedback, and the keys cannot easily be inadvertently depressed. The touch screen on the JasJar can be touched and disturbed if the user is not careful.

Overall, the JasJar is a very good wireless enabled PDA. Its size and functionality meet requirements. However, because of the non-hardened nature of the JasJar, it was not selected as the Team Leader device for the Triad prototype.

4.3.2.4 Wired SIP Phones

A wired SIP phone is designed to communicate over a standard IP network via a wired Ethernet connection using the SIP protocol. SIP wired phones were under consideration as a potential communications device for the Repair Lockers and DC Central. An extensive market survey of wired SIP phones was done with the following criteria used as evaluation guidelines.

- Fully SIP (Session Initiation Protocol) compliant
- Compatible with other Triad VoIP components

- Good Audio Quality
- Call Conferencing feature
- Headset-Ready
- Robust
- Reliable
- Cost-effective; good price point
- Text messaging support
- Security features
- Small physical size/footprint
- Bluetooth® desired for evaluation

The following wired SIP phones were selected for purchase and evaluated:

- Linksys® SPA-901
- Zultys® ZIP 2x2
- Zultys® ZIP 4x4
- Zultys® ZIP 4x5
- Polycom® IP 501
- Polycom® IP 600

4.3.2.4.1 Linksys® SPA-901

The Linksys® SPA-901 is an entry-level product and was evaluated simply as a potential phone to insert in a communications case for remote wired access. It was evaluated for that potential application due to its small size. The SPA-901 is not nearly as richly featured as the other wired IP phones evaluated for FNC. The SPA-901 provides basic telephony functionality, as well as three-way conferencing and some security options. The SPA-901 provided adequate audio quality. The SPA-901 does not support text messaging. There is no LCD display on the SPA-901.

The Linksys® SPA-901 was configured as an extension on the Zultys® MX-250 and was tested in the laboratory. Engineers were able to make calls to and from other SIP endpoints using the SPA-901.

The SPA-901's lack of text messaging and the absence of a richer feature set precluded its selection as a prototype component. The Prototype Development IPT decided not to include an entry-level wired SIP phone in the Comm Case, so the SPA-901 was not used in the Prototype configuration.

4.3.2.4.2 Polycom® IP 501

The IP501 is a three-line desktop IP telephone that has very good sound quality. It has an LCD display, phone directory, and acceptable for use with a headset, handset or in hands-free speakerphone mode. It also has dual Ethernet ports and soft keys. It a higher mid-range level phone in the Polycom® line of IP phone products. It supports text messaging.

The Polycom® IP 501 was configured as an extension on the Pingtel® SIPxchange and was tested in the laboratory. Engineers were able to make calls to and from other SIP endpoints using the IP 501 on the Pingtel® system. The Polycom® IP501 did not function with the Zultys® MX-250 although it worked well with the Pingtel® SIPxchange VoIP system. Because the MX-250 was selected for the FNC Triad prototype, the IP 501 was not selected as a Prototype component.

4.3.2.4.3 Polycom® IP 600

The IP600 is a six-line desktop IP telephone that has very good sound quality. It has a high-resolution LCD display, phone directory, and the capability to be used with a headset, handset or in hands-free speakerphone mode. It also has dual Ethernet ports and soft keys. It is a higher level phone in the Polycom® line of IP phone products. It supports text messaging.

The Polycom® IP 600 was configured as an extension on the Pingtel® SIPxchange and was tested in the laboratory. Engineers were able to make calls to and from other SIP endpoints using the IP 600 on the Pingtel® system. However, the Polycom® IP 600 worked well with the Pingtel® SIPxchange VoIP system, but it did not function with the Zultys® MX-250. Because the MX-250 was selected for the Triad prototype, the Polycom® IP 600 was not selected as a Prototype component.

4.3.2.4.4 Zultys® ZIP 2x2

The ZIP 2x2 is a lower end product in the Zultys® product line. It is not as richly featured as some other wired IP phones evaluated. It provides two LAN ports, two call appearances, a backlit graphical LCD, three-way conferencing, full-duplex speakerphone, encryption, power over Ethernet, multi-language menus, custom ring tones, multiple user login, QoS, DND, call forwarding, mute, and redial. The ZIP 2x2 provided adequate audio quality. The display is simple and adequate and the menu system is adequate. The Zip 2x2 does not support text messaging.

The Zultys® Zip 2x2 was configured as an extension on the Zultys® MX-250 and was tested in the lab. Engineers were able to make calls to and from other SIP endpoints using the Zip 2x2.

Although the Zip 2x2 has many good features, its lack of text messaging, and the absence of a richer feature set, precluded its selection as a Triad prototype

4.3.2.4.5 Zultys® ZIP 4x4

The ZIP 4x4 integrates a business phone with an Ethernet switch. In addition to four call appearances and four Ethernet ports, the device has encryption, calculator mode, single button functions, adjustable LCD, full-duplex speakerphone, headset jack, Power over Ethernet, message waiting indicator, and QoS support.

The ZIP 4x4 does support text messaging, although it is not compatible with the Jabber® text messaging software used on the project. It uses a proprietary Zultys® text messaging protocol, so it cannot exchange text messages with other vendors' devices. The display is simple and adequate and the menu system is adequate.

The ZIP 4x4 was not selected as a SIP wireless phone for the Triad prototype because the ZIP 4x5, which is discussed below, has additional features desired for the project.

4.3.2.4.6 Zultys® ZIP 4x5

The Zip 4x5 was configured as an extension on the Zultys® MX-250 and was tested in the lab. Engineers were able to make calls to and from other SIP endpoints using the Zip 4x5. The ZIP 4x5 integrates the functions of an IP phone, analog phone, Ethernet switch, and router. It has all the functions of the ZIP 4x4, plus advanced functions like firewall, Network Address Translation (NAT), Virtual Private Network (VPN), and Dynamic Host Configuration Protocol (DHCP), which allow it to be connected directly to a broadband Internet connection such as a Digital Subscriber Line (DSL) or cable modem.

The phone is referred to as a "four by five" because it has four call appearances and five circuits. Four of the circuits connect to an Ethernet LAN or broadband connection, and one circuit provides an analog connection to the Public Switched Telephone Network (PSTN).

The ZIP 4x5 supports multiple options for hands free operation. The phone includes a standard headset jack, full duplex speakerphone with acoustic echo cancellation, and Bluetooth® for use with a wireless headset. Voice activated dialing allows users to initiate calls without touching the phone.

With four external Ethernet ports, three additional IP devices such as computers, printers, and other phones can also connect to the network. The phone occupies no more space than a standard analog phone, but by incorporating the IP phone, analog phone, Ethernet switch, and IP router, it saves space on the desktop and reduces the number of ac outlets required.

The Zip 4x5 was configured as an extension on the Zultys® MX-250 and was tested in the lab. Engineers were able to make calls to and from other SIP endpoints using the Zip 4x5.

The ZIP 4x5 can behave as an intercom so that all internal calls are automatically answered by the speakerphone after one ring. It supports conferencing with three to five people. When using the key pad, users can dial a destination by phone number, SIP address, or IP address. The ZIP 4x5 provides a phone book for storing the contact information of 100 individuals. Because of the rich feature set including the built-in switches and Bluetooth® capability, and the excellent audio quality, the ZIP 4x5 was selected as the wired SIP phone for the Repair Lockers and DC Central in the Triad prototype.

4.3.2.5 SIP ATA phone adapters

Analog telephone adapters allow standard PSTN phones to functions as SIP endpoints. These adapters provided us the flexibility of interfacing with existing phone equipment where necessary. They also provide a means of getting audio out of the VoIP network for routing to other equipment in testing and future upgrades. Each end point was configured and connected to the lab network for evaluation. An analog phone was connected to evaluate sound quality and provide a means to initiate calls to other endpoints. An extensive market survey was done of Analog telephone adapters (ATA) with the following criteria used as evaluation guidelines:

- At least one FXS port
- External power supply
- SIP compatible
- Robust
- Reliable
- Cost-effective; good price point
- Security features
- Small physical size/footprint

These models were selected for purchase and evaluation:

- Grandstream® HandyTone 286 Analog Telephone Adapter
- Grandstream® HandyTone 486 Analog Telephone Adapter
- Linksys® SPA-1001 Analog Telephone Adapter
- D-Link® DVG-2001S Analog Telephone Adapter

4.3.2.5.1 Grandstream® HandyTone 286 Analog Telephone

This ATA was the lightest and smallest of the devices tested. It is a single Foreign Exchange Station (FXS) device with one LAN port and one Plain Old Telephone System (POTS) phone port. Configuration takes place either through an attached handset and voice prompts, or through a web interface accessible from the LAN port. After configuration, calls were placed to and from the device. Sound quality was evaluated as acceptable and the device functioned as expected.

4.3.2.5.2 Grandstream® HandyTone 486 Analog Telephone

This ATA is a bit larger due to the built-in router that allows other LAN devices to be connected to it and utilize a single IP address on the mail LAN. It is a single FXS device with one LAN port, one WAN port, and one POTS phone port. Configuration takes place either through an attached handset and voice prompts, or through a web interface accessible from the LAN port. After configuration calls were placed to and from the device. Sound quality was evaluated as acceptable and the device functioned as expected.

4.3.2.5.3 Linksys® SPA-1001 Analog Telephone Adapter

This ATA is a bit larger than the HandyTone 286 and a bit heavier. It is a single FXS device with one LAN port and one POTS phone port. Configuration takes place either through an attached handset and voice prompts, or through a web interface accessible from the LAN port. After configuration, calls were placed to and from the device. Sound quality was evaluated as acceptable and the device functioned as expected.

4.3.2.5.4 D-Link® DVG-2001S Analog Telephone Adapter

This ATA is the largest and heaviest of the group. It is a single FXS device with one LAN port and one POTS phone port. Configuration takes place through a web interface accessible from the LAN port. After configuration, calls were placed to and from the device. Sound quality was evaluated as acceptable and the device functioned as expected.

All tested devices worked as specified. All but one model could be configured either by an attached phone or by LAN connection and a web browser. The single exception was the D-Link® DVG-2001S, which only offered web configuration. There were minor differences in the setup of each but nothing that affected usability. Test calls placed with all devices gave similar subjective quality.

4.3.2.6 SIP Softphones

A softphone is a software application that provides telephony capabilities and enables Personal Data Assistants (PDAs), as well as PCs, to place and receive VoIP calls. SIP softphones are softphones that use the standard SIP protocol for call control. Both wireless SIP phones and wireless enabled PDAs were under consideration as a potential communications device for the On Scene Leader. PDAs require a SIP softphone application in order to facilitate SIP communications, so in the event that a PDA was chosen as the hardware for the On Scene Leader device, a softphone would need to be selected as well.

There are not many SIP softphones on the market, and some must be customized to run on specific PDA hardware. An extensive market survey was done of SIP softphones with the following criteria used as evaluation guidelines:

- Must work with preferred/selected PDA to produce reliable, high quality voice calls
- Robust

- Reliable
- User-friendly GUI
- Auto-answer feature desirable
- Conference calling, hold, transfer features desirable
- Built-in text messaging not required, but a plus

The following SIP softphones were selected for purchase or were downloaded as free trial evaluation software:

- SJPhone®
- CiceroPhone®
- X-PRO®
- Wi-Fone®
- SIPQuest® Mobile Console

4.3.2.6.1 SJPhone®

The SJPhone® (by SJ Labs) has been the most stable Softphone application evaluated in the laboratory. Engineers evaluated SJPhone® by installing and configuring it on PDAs, then making SIP VoIP calls between SJPhone® and other SIP endpoints. SJPhone® has a basic user interface that is easy to use. It provides an address book feature so that other parties can be called by simply clicking on the desired remote username. SJPhone® is relatively simple and straightforward to configure.

SJPhone® has an auto answer feature that allows the called party to be automatically connected without having to hear a ring or manually answer a call. It has 3-way conferencing, and IP-to-IP calling mode in which no SIP server (such as a Zultys® MX-250) is necessary to set up the VoIP calls. Multiple "profiles" can be configured and swapped quickly. This is useful if one PDA needs to be replaced quickly with another or if the user needs to switch to IP-to-IP mode (calling by IP addresses).

SJPhone® works on multiple PDA devices and was tested successfully on the Symbol® MC70, Symbol® MC50, and Eten® M600 PDAs. SJPhone® does not yet support text messaging, but SJ Labs is now working on a version with that functionality. This is not a major issue because we have the capability to run another client application on the PDA to perform text messaging while running SJPhone® for the voice calling and, when necessary, switching back and forth between applications.

SJPhone® was selected as a component of the Triad prototype due to its stability, ease of use, and performance. SJPhone® works well on all of the PDAs on which is was tested in the lab, including the Symbol MC70 PDA, which was selected as the On Scene Leader device for the Triad prototype.

4.3.2.6.2 CiceroPhone®

Engineers were unable to get CiceroPhone® to register successfully with the Zultys® MX-250, and support was difficult to obtain from Cicero Networks.

CiceroPhone® was not selected as a component of the Triad prototype because it did not function successfully in lab testing.

4.3.2.6.3 X-PRO

The X-PRO® Softphone from CounterPath® was evaluated on the MC70 PDA. It worked well in the laboratory. Calls were placed successfully between X-PRO® and other SIP endpoints. The 2-line functionality of X-PRO® made it more difficult to use than the SJPhone®. In addition, X-PRO® does not support the Auto Answer feature.

Although X-PRO® worked well in the lab, it was not selected as a component of the Triad prototype because it did not work well in evaluations in ex-USS *Shadwell*.

4.3.2.6.4 Wi-Fone®

The Wi-Fone® Softphone from Diamondware® was installed and evaluated in the laboratory. Wi-Fone® registered successfully with the Zultys® MX-250, but it would drop calls and the Wi-Fone® would lock up consistently when calls were established with other SIP endpoints.

Wi-Fone® was not selected as a component of the Triad prototype because it did not function properly and reliably in lab testing.

4.3.2.6.5 SIPQuest® Mobile Console

The Mobile Console Softphone from SIPQuest® was evaluated in the lab. Because there was no version available to run on the Symbol® MC70, it was evaluated on the Eten® M600 and iMate® JasJar PDAs. Although it registered successfully with the Zultys® MX-250, it would occasionally lock up in operation.

SIPQuest® was not selected as a component of the Triad prototype because there was not a version available to run on the Symbol® MC70, which was the PDA selected for the Triad prototype. In addition, it was not deemed reliable enough for selection.

4.3.2.7 Text Messaging Software

Text messaging was a required feature of the system. It allowed communication in a very small amount of bandwidth and provided an ability to converse with numerous endpoints simultaneously. As with all software components for this system, open source and industry standards were given priority when selecting candidate systems.

The selected SIP gateway supported Jabber® protocol for external messaging exclusively, so the search for candidate servers and clients was limited. Jabber® is an open standard that provides the ability to choose from a number of servers and clients from different sources.

The chat system as conceived consists of a central server, installed clients on the handhelds, and an interface with the SIP Gateway via an external messaging feature of the Gateway.

The following Text message servers were downloaded as free trial evaluation software:

- Jabber® Inc., Jabber® XCP
- Jive Software, Wildfire server

4.3.2.7.1 Jabber® XCP

Jabber, Inc. is the originator of the Jabber® standard and is the benchmark by which other Jabber® servers are compared. The Jabber® XCP server is an enterprise level, highly programmable, feature rich, instant message/presence server.

The XCP installation was very difficult, and required contacting Jabber, Inc. on more than one occasion due to inaccurate documentation. The XCP also requires a separate install of PostgreSQL®. There were issues with an install script that builds the default database for the XCP. This install script was for the Windows version of XCP. It became apparent during conversations with the tech support staff that the Linux version was their primary supported operating system with Windows being a later port. With the install issues and configuration complexity, it was decided to terminate any further testing of the XCP.

4.3.2.7.2 Wildfire® server

The Wildfire® server from Jive® software is an *open source* Jabber® protocol compliant text message server. Although more limited in scalability than the XCP, the Wildfire® server offers a large assortment of capabilities while maintaining a simple install and configuration. A separate database was not required for our install, and the configuration of the server proceeded smoothly due to the simplicity of the web configuration interface. Once configured, Jabber® clients were able to connect to the server and initiate text message sessions with each other as well as view the "presence" of their peers on the network. We did have some issues routing messages through the SIP gateway, but resolved those issues by contacting the SIP gateway technical support staff and obtaining an upgrade to the gateway and correct licensing.

The client portion of the text messaging system consisted of two possible types of clients. The handhelds, which would run a software client, and the SIP gateway that has its own text message clients would be the other. An extensive market survey was done, and a single suitable Jabber® compatible client for PocketPC was procured. The Mixe® external messaging client from the SIP gateway was also procured.

- Imov® universal mobile messenger
- Zultys® Mixe

4.3.2.7.3 Imov®

The Imov® client was installed on a number of test PDAs without incident. Once the clients were running, their presence was observed on both other clients and the server's logs. Text messages were sent between clients and received successfully.

4.3.2.7.4 Mixe®

The Mixe® client was installed on several tablet PC's. After the upgrade to the SIP gateway and the licenses the Mixe® clients worked as specified, showing presence of the external Jabber® as well as local clients. Text messages were sent from both realms successfully.

Because Jabber® is the designated protocol for text messaging, we were limited in the number of servers and clients we could test. The Wildfire® server was chosen for the final system due to its simplicity in both configuration and use. We had no problems with the server though out our testing. We were limited on the clients we could test, but the one that was available worked as specified.

4.3.2.8 Headsets

There are numerous types of headsets on the market, and these headsets have many different configurations and features. Differences among headsets include the audio connectors, the style, and whether the headset has both microphone and speaker capabilities. The style of a headset essentially refers to how it is worn and what functionality is built into it. The following items show the different types and styles of headsets:

- Over-the-head headsets
- Behind-the-neck headsets
- Wrap around the ear headsets or speakers
- "Ear bud" speakers (placed into the ear)
- "Cup" speakers (cover all or part of the ear, or both ears)
- Both microphone and speaker can be incorporated into a headset design
- Boom microphones (hang near the side or front of the face)
- Throat microphones (strapped to the throat)
- In-line microphones (located in the headset wiring; hang near the side of the face)
- Bluetooth® headsets (operate wirelessly)

The Prototype Development IPT looked at the following types of headset audio connectors, in addition to Bluetooth® headsets:

- Single connector 3.5mm

- Two connector 3.5mm (common with PC's)
- Single connector 2.5mm (common with PDA's and wireless phones)

The selected On Scene Leader device, the Symbol MC70 PDA, has a built-in 2.5mm headset jack. The Azden® units, selected for the Sound Powered Phone interface, use two 3.5mm connectors.

In terms of style, ergonomics, and functionality, compatibility issues result in fewer potential headset options for personnel who are wearing Personal Protective Equipment (PPE). Conversely, for personnel who are not wearing PPE, there is a wider range of possibilities for their headset options. For wired headsets, engineers desired to look at a number of options and give alternatives to shipboard personnel with regard to their headset choice. Headsets "fit" people differently, and some personnel prefer certain styles to others. Engineers generally grouped headsets into the following categories:

- Ear bud and microphone headset
- Over-the-head headset
- Over-the-ear and boom microphone headset
- Throat microphone with separate ear bud speaker
- Behind-the-neck headsets

For wireless headsets, operators evaluated several headsets that use Bluetooth® technology. Bluetooth® technology allows for a wireless exchange of audio between the headset and its "host" device (a PDA or PC, for example).

With those thoughts in mind, the Prototype Development IPT conducted a market survey of headsets with the following criteria used as evaluation guidelines:

- Robust
- Reliable
- Comfortable for use over a several hour timeframe
- Noise-canceling technology desirable but not required
- The On Scene Leader headset:
- Must work with preferred/selected PDA and/or the wireless SPP interface to produce reliable, high quality voice calls
- Must not compromise the facial seal of breathing apparatus
- Must be able to be worn comfortably under a firefighting helmet and with other PPE

The following Bluetooth® (wireless) headsets were chosen for evaluation as well:

- VXI® Blue Parrot B200
- GN Netcom® Jabra JX10

- Motorola® HS850
- Plantronics® Voyager 510SL
- GN Netcom® GN 6210
- GN Netcom® Jabra BT250V
- Plantronics® Discovery 640
- Motorola® H500

Operators evaluated these eight Bluetooth® headsets in the FNC Lab. Each in turn was wirelessly connected to the Symbol® MC70 PDA and VoIP calls were tested as the engineers roamed throughout the FNC Lab and the *MTS* office suite. Engineers subjectively rated the headsets based on audio quality and ergonomics (level of comfort).

Although some Bluetooth® headsets were rated higher than others were, none received a "good" audio rating. Most headsets had some level of audio chop, background hum, or muffled sound. Doubts were raised about how this technology would perform in the higher noise environment of a ship. In addition, using Bluetooth® technology adds another level of complexity and therefore potential failure to an already challenging Damage Control communications scenario.

The Prototype Development IPT determined that Bluetooth® was not the best and most prudent choice for a headset technology for the Triad prototype because of the less than stellar audio quality observed in lab evaluations and the added "layer" of using yet another wireless technology.

The following "wired" headsets/microphones/speakers were chosen for the final evaluation process:

- Earmark® Throat Microphone (no speaker included)
- Panasonic® KX-TCA92 (over-the-head; one-ear cup speaker and boom microphone)
- Plantronics® MX-100 (ear bud speaker and in-line microphone)
- Shure® QuietBoom (over-the-ear speaker and boom microphone)

4.3.2.8.1 Earmark® Throat Microphone (Microphone Only)

Operators evaluated the Earmark® Throat Microphone in the laboratory. The Earmark® was evaluated with the Symbol® MC70 through a Y-adapter manufactured by *MTS* engineering. It was also evaluated with the wireless SPP interface. The FNC engineer used the Earmark® throat microphone and a set of ear bud speakers to communicate with another engineer over the VoIP and SPP paths. The Earmark® was found to produce very good audio quality in all cases.

Because of its very good audio quality as observed in lab evaluations, the Earmark® throat microphone was selected as a component of the Triad prototype in the "throat microphone" category. A separate ear bud speaker would have to be selected to use along with the Earmark® throat microphone.

4.3.2.8.2 Panasonic® KX-TCA92 Over-The-Head Wired

The Panasonic® KX-TCA92 is an over-the-head headset with a one-ear cup speaker and a built-in boom microphone. It has a 2.5mm connector that allows it to plug directly into the Symbol® MC70 PDA. The wearer can adjust the volume of the KX-TCA92 and can mute the audio through an external control in-line with the wiring.

Operators evaluated the KX-TCA92 in the lab by connecting it to the Symbol MC70 PDA and making a series of VoIP calls to other VoIP endpoints in the laboratory. The KX-TCA92 was comfortable to wear and produced very good audio quality. It also exhibited good stability in that it did not shift around on the head during movement.

Because of its very good audio quality, stability, and comfort, as well as its external volume/mute control, the Panasonic® KX-TCA92 headset was selected as a component of the Triad prototype in the "over-the-head headset" category.

4.3.2.8.3 Plantronics® MX-100 Ear Bud/In-Line Microphone

The Plantronics® MX-100 is a headset with an ear bud speaker and an in-line microphone. It has a 2.5mm connector that allows it to plug directly into the Symbol® MC70 PDA. The wearer can adjust the volume of the KX-TCA92 and can mute the audio through an external control in-line with the wiring.

Operators evaluated the MX-100 in the lab by connecting it to the Symbol® MC70 PDA and making a series of VoIP calls to other VoIP endpoints in the laboratory. The MX-100 was comfortable to wear and produced very good audio quality. It also exhibited good stability in that it did not shift around during wearer movement. Its design includes a built-in rubber clip that grips the ear lobe and keeps the MX-100 in place.

Because of its very good audio quality, stability, and comfort the Plantronics® MX-100 headset was selected as a component of the Triad prototype in the "ear bud and microphone" category.

4.3.2.8.4 Shure® QuietBoom Over-The-Ear/Boom Mic

The Shure® QuietBoom is a headset with an over-the-ear speaker and a boom microphone. It has a 2.5mm connector that allows it to plug directly into the Symbol® MC70 PDA. Engineers evaluated the QuietBoom in the laboratory by connecting it to the Symbol® MC70 PDA and making a series of VoIP calls to other VoIP endpoints in the Lab. The QuietBoom was comfortable to wear and produced very good audio quality. Its design includes an over-the-ear clip and an ear bud speaker that keeps the QuietBoom in place. It exhibited good stability in that it did not shift during movement.

Because of its very good audio quality, stability, and comfort the Shure® QuietBoom headset was selected as a component of the Triad prototype in the "boom microphone" category.

4.3.3 RF Interface to Sound-Powered Phone (SPP)

The laboratory audio test bench was configured to permit examination of typical audio components found in any SPP communications system. The initial Triad concept imposed no constraints as to whether or not wireless SPP transceivers and interfaces should be located at each node, or be integrated with other pathways' components in individual Comm Cases. Either approach could allow a Team Leader, or other DC personnel, to roam untethered through several zones (similar to the act of roaming amongst multiple APs), while maintaining seamless communications. As the Triad prototype architecture evolved, some refinements were back fitted into early designs based on results discovered during parallel development of the three Triad paths. Belt packs to accommodate discreet transmit and receive units requiring no Push-To-Talk button were envisioned for the Team Leader or other DC personnel making use of a Comm Case, providing hands-free untethered operation.

Engineers understood that,

- By intent the SPP path would not introduce a circuit ground to the shipboard SPP network which electrically "floats"
- That negligible current would be introduced into that system by the Prototype's relatively low operating voltage
- Audio signals presented would not be of sufficient amplitude to damage SPP elements or harm personnel
- There would be no degradation of normal shipboard SPP functionality while operating the wireless interface
- Shipboard SPP system shall not exhibit any electrical continuity to the hull, or to any other ship structure or system

During the first (non-working) visit to the ex-USS *Shadwell*, members of the Prototype Development IPT observed the type of SPP equipment installed and used by ship's force personnel, and efforts were made to procure identical components for design and construction of an SPP network at the lab. Since circuit conditions and performance in a "typical" SPP system vary widely, some assumptions were made concerning design and construction of a lab test bench and a network intended to be used to evaluate suitability of candidate components. Among these were:

- Utilizing in the lab, as much as practical, the same make, model, and configuration of shipboard SPP components would increase the reliability of this portion of the Triad prototype, since those items have a long history of usage in a variety of harsh environments.

- A “standard” SPP transducer (element) performs better as a speaker than as a microphone, in its usual configuration. That is, if an improved quality audio signal is presented to an existing SPP system, that improvement is capable of being preserved and experienced at the stations of the listeners, using standard SPP receiving elements. In addition, vocals produced by SPP elements may be received by the user of a wireless interface device, exhibiting improvement when compared to the same signals being received by standard SPP element.

- In practice, the number of transducers “on-line” at any given time is unknown. Because of this, the “nominal” circuit impedance of the interface could become the critical factor regarding performance, and could easily be responsible for the reduction or elimination of any potential benefits gained by an improved transducer.

- Realistically, the electrical and mechanical condition of the individual devices in the shipboard circuits, as well as the circuitry itself, will be to some extent less than ideal, which could lead to difficulty in attempts to duplicate their behavior in the lab, using new equipment.

Mindful of these assumptions, a stand-alone SPP network was created comprised of a master switching/coupling station, three portable stations with Call boxes, a wall-mounted Callbox, and various nodes for patching audio signals. Some stations were located in relatively quiet areas, others in constant ambient noise, while the portable units could be positioned where desired for specific testing configurations. Some SPP cable runs on this network were installed in the overhead plenum, for considerable lengths parallel to nearby AC power conduits, fluorescent lighting fixtures, fire alarm circuits, and LAN cable bundles and drops, and passed through building fire stops at some locations, as well. WLAN components and other 802.11x devices were also operating in the immediate vicinity, intending to provide a “worst-case scenario” to challenge the performance of prototype Triad path designs.

This apparatus was used for the purpose of direct injection of low-level audio to the network from signal generators to record the performance of components and their effect on the systems’ nominal performance. Combinations of devices such as audio transformers, transmitters, receivers, capacitors, resistors, SPP elements and microphone and speaker varieties were examined, while their impact on the behavior of the SPP network was observed. The resulting analog output of the tests could be recorded for further analysis. Several examples of these types of data are short sound bites and their corresponding screen shots, illustrating relative signal amplitude information, and measures that could be taken to prevent audio clipping, for one matter. One example of data recorded for additional analysis is the recording of short sound bites with their corresponding screen shots. This data provided information on relative signal amplitude and analysis indicated measures that could be taken to prevent audio clipping.

Terminal strips at the master station and several of the portable units allowed devices to be paralleled to that particular branch circuit which expedited measurement of parameters such as electrical DC resistance; frequency response of elements. Overall circuit impedance as "seen" by a coupling transformer; average signal amplitude produced by an SPP element; maximum signal amplitude tolerated by an element before saturation occurs and produces audio distortion; "normal" background noise on the line, and so forth. Individual transducer elements contained in handset and head/chest set circuits, as well as discreet elements, could be conveniently arranged to discover their electrical and acoustic properties, especially when operated with numerous units on-line simultaneously. Extensive recordings were not deemed necessary, as subjective evaluation of vocal quality and volume appeared to be a more practical approach.

An initial market survey of sources for U.S. Navy SPP components manufactured by Dynalec® Corporation had revealed a limited number of suppliers. Some desired items had as much as a 180-day lead-time, but most critical devices were in stock from Kinnaman Electric, Inc. Prior to trial in ex-USS *Shadwell*, a one-way audio interface module was designed and tested in the lab. As SPP elements function efficiently at approximately 125 millivolts, it was realized that an ear speaker monitor output from a relatively low-powered radio receiver should provide sufficient drive for such a circuit. A legacy pair of transmitters/receiver units was employed to inject an audio signal into the test network through an audio transformer with a 1:1 turns ratio. This provided necessary isolation to exclude receiver operating voltages from the SPP line, and presented an acceptable insertion loss. The Triad Magnetics® model TY-146P unit features two primary windings and two secondary windings. For this application, one of the secondaries was connected directly to the SPP line, and one primary was driven by the ear speaker monitor output of an Azden® WR Pro receiver, which is electrically expecting to "see" 30 ohms. A variety of microphone types, mostly electrets, was used to drive the WM Pro transmitter. These transmitter/receiver pairs can operate on either of two channels selectable by an external sliding switch actuator.

Using this basic set-up, one could roam from the vicinity of the receiver, and the quality of the audio received by SPP handsets and head/chest sets connected at different stations was subjectively evaluated for fidelity and volume. This interface method did not degrade the normal performance of other receivers simultaneously connected. However, these radio units have no controls for microphone signal level or output gain level.

Operators discovered that the received volume would often become uncomfortably loud, and distortion would occur unless steps were taken to attenuate the audio signal with a so-called microphone output control (MOC), which was inserted between the microphone and the input of the wireless audio transmitter. This device allows the user to dial a numerical setting within the range of 000 to 999 through ten complete rotations of the control, and increases the amount of audio signal attenuation as the number setting increases. For convenience, a rocker switch on the unit opens the microphone input circuit to facilitate testing and measurement. This method does not disturb the "normal" circuit conditions of the SPP system, and allows quick substitution of microphones for sequential listening evaluation. It was decided to test this one-way scheme in ex-USS *Shadwell*, to determine if long SPP circuit runs of an undiscoverable architecture and the possibility of interference from a variety of sources would prevent acceptable performance.

The wireless receiver and the related components were housed in a cast-metal enclosure with several cable pass-through openings. The receiver antenna was allowed to protrude through a rubber grommet in the top surface of the box. This arrangement is designated as Model 1, and was placed in a small "Pelican®" case resembling a suitcase. Approximately six feet of SPP cable terminated with a plug was passed through the case, providing a conceptual, functioning stand-alone unit. An internal toggle switch opens the SPP circuit, allowing the suitcase to be taken "off-line" for adjustment or reconfiguration of components without the need to unplug the SPP connector.

The two-channel limitation of the Azden® PRO devices necessitated a search for units with more features, with identical connectivity requirements. The choice of the Azden® 10BT transmitter and 100UPR receiver was ideal for this purpose, They allowed fine control of microphone gain, as well as output level adjustment. A balance was achievable between the belt pack units and the Comm Case counterparts, as far as overall talk and listen volume, depending on the individual microphone and/or speaker chosen by the operator. At the same time, it was not terribly difficult to prevent overdriving the line and consequently distorting the reproduction of the audio at the SPP instrument's end.

A size reduction was desired for the following interface model. The original audio transformer used in development was replaced by a design possessing a smaller footprint, and different operating characteristics. Instead of the large unit that contained two discreet primary windings and two secondary taps, a model with only one primary was selected. In reality, the primary was employed as the functional single secondary driving the line, with the secondaries regarded as a primary input for audio out of the Case transmitter, and audio in for the Case receiver. This arrangement provided the desired side-tone as a system feature for audio presence that allows for easier adjustment of nominal settings, if units must be replaced.

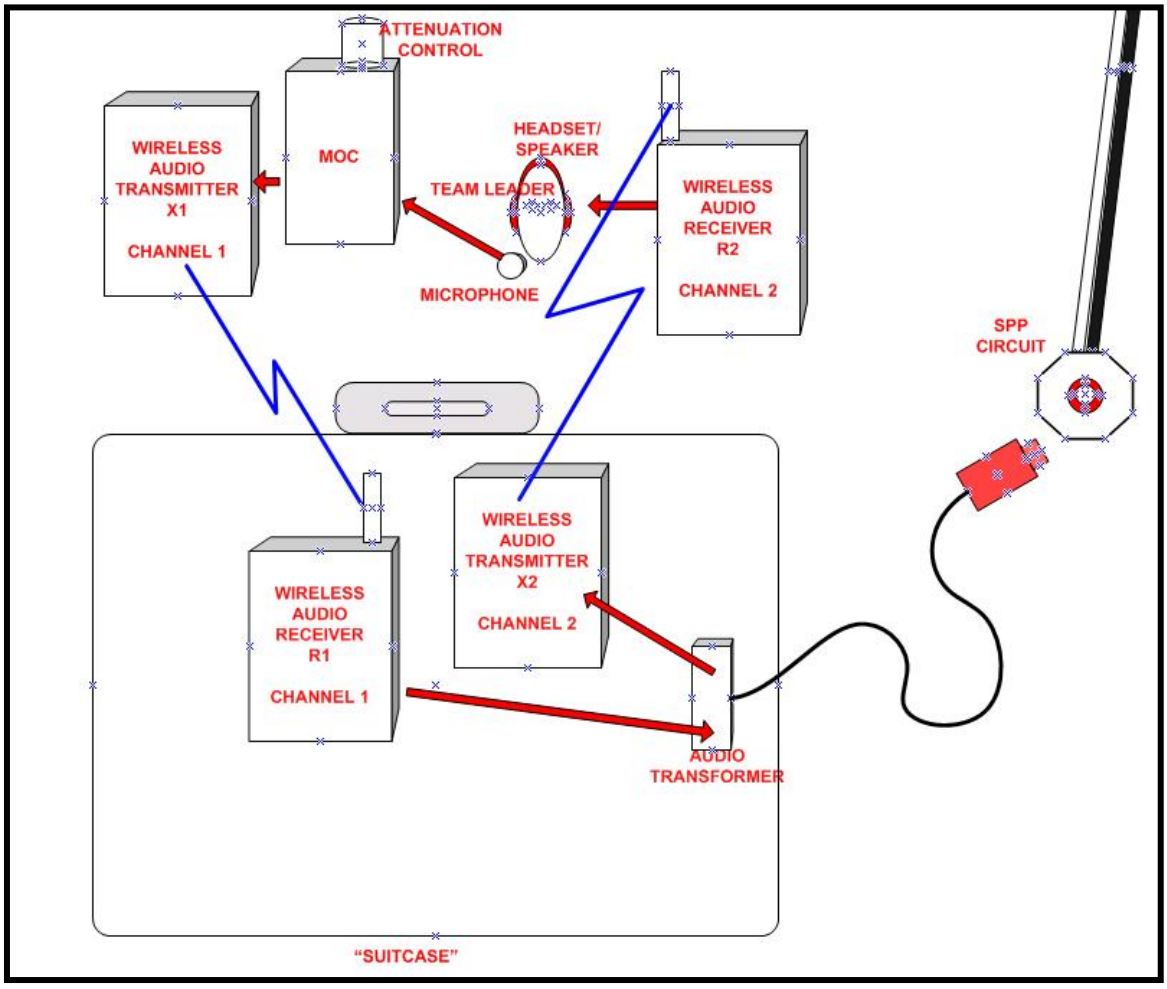

Figure 2 – General Component Arrangement for initial ex-USS *Shadwell* Wireless SPP Interface Testing

5.0 Laboratory Testing and Integration

5.1 General Description

Initial laboratory testing was conducted on each path independently to identify attributes, define characteristics, and specify performance measures to determine suitability for shipboard use and integration feasibility. The Prototype Development IPT developed the prototype communications capability from selected candidate component technologies and conducted laboratory tests to ensure interoperability and integration of all paths. To test performance of each candidate component in the shipboard setting under simulated emergency conditions, IPT members transported candidate equipment to ex-USS *Shadwell* for integration and interoperability testing of communications paths. Prior to requesting time aboard ex-USS *Shadwell*, the Prototype IPT

developed detailed equipment installation and experiment plans to focus on specific communications capability components and the methods of testing and verifying test results. The Analysis IPT evaluated the performance and analyzed the test results of the Triad communications prototype, provided test results, and the overall evaluation to all concerned. Both IPTs followed the standards set forth in the following documents as much as practical:

- MIL STD 202 (Test Method Standard for Electrical and Electronic Equipment)
- MIL STD 2036A (General Specifications for Electronic Equipment), MIL STD 220B (Test Procedures for filtering for EMI/RFI)
- MIL STD 461E (Standards for the Control of EMI/RFI)
- MIL STD 810F (Environmental Engineering Considerations and Laboratory Tests)

The Prototype Development and Analysis IPTs collaborated with the ex-USS *Shadwell*'s WLAN administrator to expand the wireless LAN in the ship to the extent necessary to ensure a realistic demonstration of the Triad communications prototype. Ex-USS *Shadwell* personnel assisted the Prototype Development IPT with the installation of the network hardware necessary to extend the network backbone and to expand the coverage of the WLAN.

5.2 Powerline Communications

5.2.1 Telkonet® PLC

The Prototype Development IPT installed the Telkonet® Powerline components in the lab. The Telkonet® Gateway was connected to the Telkonet® coupler, which was connected to a circuit breaker in the main electrical sub-panel. The Gateway injects the PLC signal via the coupler into the AC power infrastructure. The Gateway can also be connected to the LAN providing access to the LAN at any AC receptacle serviced by the sub panel. Telkonet® iBridge® units were then plugged into the AC outlets, which provided the Ethernet connection to access the LAN over the power lines. Overall, the system was very reliable and consistently provided network speeds greater than 4 Mbps.

The Telkonet® system was installed in ex-USS *Shadwell* using one Gateway, one eXtender® and two couplers. It was initially installed in one day. Later the installation was modified to connect the eXtender® and Gateway paths of the system.

The Telkonet® Powerline communications system was tested and integrated with the VoIP over WLAN communications path in the laboratory setting. This would allow one communications device to function over both WLAN and PLC communication paths. Since the PLC communications provided a 10/100 base-T port at any AC outlet, this could be used to connect any IP device. It was determined that connecting an Access Point to the PLC Network using a Telkonet® iBridge® would facilitate VoIP communications. This was subsequently tested successfully.

5.3 Voice over Internet Protocol (VoIP)

5.3.1 Vocera® Communications System

The Vocera® communications system consist of server software and communications badges. In order to become familiar with the Vocera® system, and to eliminate any potential conflicts or interference with the LAN backbone in the office building in which the lab resided, the initial testing of the Vocera® system was performed on a dedicated, standalone IP network which consisted simply of a Proxim® Orinoco AP-2000 connected directly to the Poweredge® server.

Operators installed the Vocera® server software on a Dell® Poweredge® 1800 server in the laboratory. The Vocera® Administration Console was utilized to configure several users on the system. The users were called Team Leader, DC Central, Repair Locker 1, and Repair Locker 2. A Proxim® Orinoco AP-2000 wireless access point (AP) was connected to the Poweredge® server and configured. An AP was required for the wireless Vocera® badges to communicate with each other and to locate the server for configuration information.

Operators initialized and configured the Vocera® badges, and then proceeded to make VoIP calls between badges on the dedicated IP network. Engineers tested many of the capabilities of the Vocera® system and found that it worked well in the laboratory environment. A second AP-2000 access point was configured and placed in a location on the other side of the laboratory. Operators tested the roaming ability of the Vocera® badges and found that it was possible to roam throughout the lab area and throughout the laboratory and operators even roamed onto other floors of the building.

Operators demonstrated the Vocera® system to NRL personnel during the Quarterly Progress Review (QPR) at the laboratory in November 2005. The Vocera® system was also integrated onto the laboratory LAN so that Operators could verify that it would seamlessly operate on an existing LAN, such as that in ex-USS *Shadwell*.

5.3.2 Zultys® VoIP System

The Zultys® MX-250 Enterprise Media Exchange system is a single box (3.5" high) which supports from 5 to 250 VoIP users without additional hardware. It combines the functionality of a PBX, voice mail server, and voice gateway and, in addition, it supports features like instant messaging. The MX-250 and several Zultys® wired IP phones were purchased for evaluation as components of a potential VoIP system for the Triad prototype.

Engineers set up the MX-250 and three Zultys® phones (the ZIP 2x2, the ZIP 4x4, and the ZIP 4x5), on a dedicated standalone IP network through a Dell® Ethernet switch. Using Zultys®' browser-based administrative tool, engineers configured the system and placed VoIP calls successfully between the ZIP phones. The Zultys® MXIE Softphone was loaded on two PC's to allow computer integration with the phones and to allow instant messaging among users. Zultys® provided FNC engineers with a Zultys® WIP2 wireless IP phone, and after a Proxim® AP-2000 wireless access point was added to the network infrastructure, operators were able to place VoIP calls between the WIP2 wireless phone and any of the ZIP wired phones.

Prototype development operators demonstrated the Zultys® system to NRL personnel at the first QPR at the laboratory in November 2005. Over time, several other wireless IP phones and PDAs running Softphones were incorporated into the Zultys® system for lab evaluation. The Zultys® system was also integrated onto the laboratory LAN in order for operators to verify that it would seamlessly operate on an existing LAN, such that in ex-USS *Shadwell*.

5.3.3 Vocera® – Zultys® Integration

Because the Vocera® and Zultys® systems were under consideration to be used together in a complementary fashion in the final Triad prototype, Prototype Development IPT members had an objective of integrating the Vocera® and Zultys® systems together such that VoIP calls could be seamlessly placed between endpoints (wireless badges, wireless phones, PDA's, wired phones) attached to either system.

Because the Vocera® and Zultys® systems use different call control protocols, the two systems are not inherently compatible with each other in terms of allowing calls to be exchanged. Engineers determined that the two systems could be integrated through analog trunking; that is, calls going back and forth between Vocera® and Zultys® would have to traverse an analog connection to "bridge the gap" between the two systems.

To enable the integration, an Intel® Dialogic telephony interface board was installed in the Dell® Poweredge® 1800 server (which was running the Vocera® software), and a Zultys® FXS interface board was installed in the Zultys® MX-250. These two interface boards were connected to each other with analog telephone cables. The Vocera® Administration Console, the Vocera® Telephony Server, and the Zultys® MX-250 were all configured to enable analog trunking. The result was that VoIP calls were successfully placed between Vocera® badges and any of the endpoints connected to the Zultys® system.

5.4 RF Interface to Sound Powered Phone (SPP)

The Prototype Development IPT designed and developed an interface that converts RF signals into audible voice of amplitude sufficient to create an analog signal for transmission over the SPP circuit to provide a last resort communications path that leaves the On-scene Leader un-tethered. Prior to trial in ex-USS *Shadwell*, a one-way audio interface module was designed and tested in the lab. Using a wireless audio transmitter (Azden® WM-PRO) and any one of a variety of microphones, vocals were injected into the SPP test system through an audio transformer driven by the output of the wireless audio receiver (Azden® WS-PRO). The secondary of the transformer was connected directly to a number of different input jacks located throughout the paths of the system. The quality of the audio received by SPP handsets and head/chest sets connected at different stations was subjectively evaluated for fidelity and volume. This interface method did not degrade the normal performance of other receivers connected to the circuit. It was found that the received volume would often become uncomfortably loud, and distortion would occur unless steps were taken to attenuate the audio signal with a so-called microphone output control (MOC), which was inserted between the microphone and the input of the wireless audio transmitter. This device allows the user to dial a numerical setting within the range of 000 to 999 through ten complete rotations of the control, and increases the amount of audio signal attenuation as the

number setting increases. For convenience, a rocker switch on the unit opens the microphone input circuit to facilitate testing and measurement. This method does not disturb the "normal" circuit conditions of the SPP system, and allows quick substitution of microphones for sequential listening evaluation.

The wireless receiver and related components were housed in a cast-metal enclosure with several cable pass-through openings. The receiver antenna was allowed to protrude through a rubber grommet in the top surface of the box. This arrangement is designated as Model 1, and was placed in a small Pelican® case resembling a suitcase. Approximately six feet of SPP cable terminated with a plug was passed through the case, providing a conceptual, functioning stand-alone unit. An internal toggle switch opens the SPP circuit, allowing the suitcase to be taken "off-line" for adjustment or reconfiguration of components without the need to unplug the SPP connector.

The Pelican® "suitcase" is large enough to contain both Model 1 and Model 2 components. When operating the transmitter/receiver pairs on different channels, and combined with a MOC, the configuration is designated as Model 3, and allows the user to connect to a SPP jack, and standoff at some distance, maintaining full-duplex communication with other SPP talkers. This design allows easy substitution of radios and microphones for developmental purposes, and can be operated over the length of any necessary extension SPP cable. Of course, roaming distance for the user is limited by the performance of the two separate wireless audio links, and there is a possibility that either side of the conversation could drop out, leaving the other functioning. Total operation has been shown to resume if the user relocates. Generally, full volume is maintained by this arrangement for either side of the conversation until one of the radio links drops, rather than presenting a gradual decrease in performance to the point of marginal usefulness.

6.0 On-Site Testing

6.1 Overall Plan

On-Site Testing

Prior to this project, the ex-USS *Shadwell* wireless LAN (WLAN) included five Proxim® AP-2000 access points (APs). These initial APs were 802.11b only, and they were located at the following locations:

- Main Deck: 1-19-1, 1-21-2,
- 2nd Deck: 2-10-1, 2-18-2, and 2-19-2 [4].

NRL personnel expanded the ex-USS *Shadwell* WLAN to the other decks in the Test Area by adding a number of access points and adding 802.11g and 802.11a capability on all access points. Additional access points were procured as well as necessary ancillary equipment such as NEMA enclosures; 802.11a and 802.11b/g upgrade kits, Netgear® Ethernet switches, and power outlet strips, and delivered them to NRL for configuration and subsequent installation in ex-USS *Shadwell*.

Eleven new APs were installed at the following locations prior to the contractor's February 2006 visit to ex-USS *Shadwell*:

- 01 Level: 01-43-2, 01-29-3, 01-22-2, and 01-22-1
- 3rd Deck: 3-15-1, 3-22-1, 3-29-1, 3-15-2, 3-24-2, 3-29-2
- 4th Deck: 4-30-4.

There were 16 access points in the Test Area in February 2006 at the time of the FNC team's first work trip to ex-USS *Shadwell*.

6.2 Initial Coverage Results

6.2.1 Work Trip One – 06-10 Feb 2006

During the first on-site work trip to ex-USS *Shadwell* [4], engineers conducted a passive 802.11a and 802.11b/g wireless coverage survey to determine overall wireless coverage throughout the designated test area. The results of this survey indicated the requirement to move an already existing AP and to install an additional AP to ensure adequate wireless coverage.

One AP was relocated from 3-12-1 to 4-19-1. The new AP was added near the platform at 2-29-0.

The VoIP team completed the following work during the period:

- Noise Floor Analysis in entire Test Area for 802.11b/g
- Passive Wireless Coverage Survey in entire Test Area for 802.11a and 802.11b/g
- Subjective evaluation of wireless coverage in Test Area via IP phone calls using the following endpoints:
  - One wired Zultys® ZIP 4x5 Phone connected to LAN near 01-43-01
  - Two wireless Symbol® MC50 PDA's using SJPhone® Softphone
  - Two wireless Zultys® WIP2 Phones
  - One wireless Tablet PC running SJPhone® Softphone

Note: The Symbol® MC50 PDA was the endpoint most frequently used in the subjective IP call evaluation.

The initial testing and observations showed that the 802.11b/g noise floor in ex-USS *Shadwell* was approximately -95dBm. Color-mapped reports of signal strength for each deck in Test Area showed overall signal strength and wireless coverage [4][5]. Subjective IP phone call evaluation on all decks revealed good quality on IP calls throughout all decks in the Test Area with the following exceptions:

- Subjective IP phone call evaluation showed areas of poor coverage and poor IP call performance forward of frame 22 on 4th deck. Recommended relocation of wireless access point (AP) formerly located at 3-12-1 to 4-20-1. After relocation of the AP, subsequent IP call testing and wireless surveys on both the 3rd and 4th decks showed that 4th deck coverage issue was resolved, and the level of coverage on 3rd deck did not diminish due to relocation of the AP.

- Survey reports and IP call testing both indicated what appeared to be areas of weak signal strength in the Main Deck Test Area aft of frame 29 in both port and starboard passageways. These results required further evaluation during subsequent work visits.

The Prototype Development IPT completed all of its objectives during this initial work week aboard ex-USS *Shadwell*. Observations and validations enabled accurate diagrams to be produced, which resulted in the reduction of time required to set up and complete future work [4][5]. The electric power distribution system was marked so that PLC systems could be readily installed and tested during subsequent work weeks.

The electric power distribution system was investigated and surveyed [4][5]. The ship deck diagrams were marked so that a PLC system may be readily installed and tested during subsequent workweeks. The electrical distribution system survey included locating the AC sub-panels servicing the AC outlets in the test area onboard ex-USS *Shadwell*. The receptacles in the test area were located and identified by deck and frame location and the available circuit information was recorded.

During the work period, the SPP Team determined that while a number of SPP circuits were available aboard the ship, the 1JV (Maneuvering and Docking) Circuit was the only circuit that was operational throughout the test area. Further, any area of the ship within the designated test area could be covered by the installation of a temporary SPP line connecting the DC command and control node with the Rapid Response Team (RRT) Leader. Initial testing of the prototype wireless interface produced positive results. A table containing Sound Powered Phone node assignment and signal quality by location is available in Appendix A.

Although much more testing needed to be done with wireless endpoints to determine more precise performance data for each specific endpoint under evaluation, initial observations of the VoIP prototype system indicated that a signal strength of approximately -70dBm or worse, and a signal-to-noise (S/N) ratio of approximately 30 dB or worse, can produce poor performance in IP calls when using a Symbol MC50 PDA as the wireless endpoint. These stated dB levels reflect initial, approximate, and informal observations only, and performance will very likely vary between endpoints based on each specific endpoint having different characteristics such as transmit power, antennas, and audio capabilities. These factors may allow some endpoints to provide better quality IP calls at lower signal strength and/or higher S/N ratios than other endpoints.

Work Trip One Recommendations

- Continue development of the wireless interface prototype to include two-way communications capability.
- Install and initially test a candidate PLC system aboard ex-USS *Shadwell* during the next scheduled work week.
- Conduct an Active Wireless Coverage Survey aboard the ship within the designated test area to determine the speed and throughput of voice and data for the VoIP prototype system.

6.2.2 Work Trip Two – 06-10 Mar 2006 [4]

6.2.2.1 VoIP Communications

The VoIP Team verified AP and wireless card information (locations, serial numbers, MAC addresses, etc.) and completed active WLAN surveys (802.11a and 802.11g) for each deck in the Test Area using AirMagnet® Surveyor PRO. For the "active" survey, Surveyor PRO software "associates" (connects) with a particular AP, gathers data, and then it associates with other AP's as the surveyor roams.

Additionally, the Team completed 802.11a and 802.11g RF spectrum analysis surveys for each deck in the Test Area using the Anritsu MS2721A Spectrum Master. Results of the 802.11a/g RF spectrum surveys are included in the L. Robert Kimball & Associates report that is part of the Work Trip Two report [5].

The Prototype Development IPT installed the Zultys® MX250 IP PBX (VoIP Server) on 01 Level (01-43-2) and three Zultys® ZIP 4x5 wired IP phones (two near 01-43-2 and one in Repair Locker 2 (2-9-1-Q)). Upon installation, the Team performed some preliminary VoIP call evaluations over the WLAN and LAN using wired and wireless IP endpoints.

Engineers performed VoIP call evaluations as time permitted. Comprehensive call evaluations were not completed for each endpoint on each deck due to time constraints. The following evaluations were conducted using the listed endpoints on the listed decks:

- Hitachi®IP5000 Phone: 01 Level, Main Deck, 2nd and 3rd Decks

- Symbol® MC50 PDA: Main Deck, 2nd, 3rd, 4th, and 5th Decks
- Zultys® WIP2 Phone: Main Deck and 2nd Deck

During these evaluations, operators found and documented areas of poor VoIP call quality and noted areas where communication was impossible [4][5]. Surveys and IP call assessments under material condition ZEBRA showed a number of locations within the designated test area that needed further evaluation and/or WLAN modifications in order to produce complete coverage and high call quality.

The analysis and recommendations focused on the 802.11g data, because the endpoints that were used for VoIP call evaluation are all 802.11b/g devices, and because the 802.11b/g signal propagates better than 802.11a in the environment present in ex-USS *Shadwell*.

Based upon this analysis, Appendix B of the Work Plan Two report contained recommendations for adjusting the ex-USS *Shadwell* WLAN components to improve call coverage and performance [4][5].

6.2.2.2 Powerline Communications (PLC)

The Telkonet® PLC system was installed onboard the ex-USS *Shadwell* during the second work trip. The PLC Team included contractors and an ex-USS *Shadwell* Electrical Technician to perform the physical installation of the Telkonet® PLC equipment and cables. A Telkonet® representative also participated in the installation process.

Based on the information obtained during the previous work session the Telkonet® couplers were installed beginning with power sub panels servicing the receptacles on the Main Deck, 2nd, 3rd, 4th and 5th Decks and the sub-panels servicing receptacles on the 01 Level and the 02 Level Control Room. The PLC Team additionally installed the required couplers within ten feet of each sub-panel and installed a power disconnect switch or an additional circuit breaker in the power sub-panel. The Team installed a Telkonet® iBridge® into an AC outlet in Repair Locker 2 (Compartment 2-9-1-Q). Finally, Engineers installed the Telkonet® Gateway and connected it to the ex-USS *Shadwell* WLAN and to the coaxial cables from the Telkonet® couplers.

Engineers identified the following panels as directly supplying power to the receptacles on decks indicated in parenthesis:

- 02-43-3 (02 level Control Room)
- 02-43-1 (01)
- 01-46-1 (01)
- 1-18-1 (01)
- 1-40-1 (01)
- 1-20-1 (01, Main, 2nd, 4th)
- 1-30-1 (Main, 2nd)

- 1-30-2 (01, Main)
- 1-39-2 (01)
- 2-9-1 (2nd, 3rd)
- 2-10-3 (2nd)
- 2-15-2 (2nd, 4th)
- 2-31-1 (2nd, 3rd, 4th)
- 2-32-1 (2nd, 3rd)
- 2-32-2 (3rd)
- 3-42-1 (Main, 2nd, 3rd, 4th, 5th)

Engineers determined that panel 2-10-1 supplies power to all the following panels:

- 1-18-1
- 1-30-1
- 1-30-2
- 2-9-1
- 2-10-3
- 2-15-2

Panel 1-45-1 supplies power to the following sub-panels:

- 02-43-3
- 01-46-1
- 1-20-1
- 1-39-2
- 1-40-1
- 2-31-1
- 2-32-1
- 2-32-2
- 3-42-1
- 2-69-1

Based on the power distribution scenario and recommendations from the Telkonet® representative, engineers installed a Telkonet® Medium Voltage Coupler (3 phase connections, 1 neutral connection) and Telkonet® Gateway at panel 1-45-1 and a Telkonet® Delta Phase Coupler (3 phase connections) and eXtender® at panel 2-10-1. Engineers installed a Delta Phase Coupler on panel 2-10-1 because there were no neutral connections available.

The ship's electrician installed the couplers at the power distribution sub-panels. Further investigation revealed that panel 2-10-1 did not have adequate provision for the installation so Engineers connected the coupler to the feed from 2-10-1 inside adjacent panel 2-10-3. A fused 20 Amp disconnect switch was installed in between the coupler and the connection in panel 2-10-3. Both components were mounted on the bulkhead in Repair Locker 2. The 3-phase connection to panel 1-45-1 was made on the Furnas unit on the DC power supply adjacent to the panel, which provided an 18 Amp overload relay. The neutral connection was made inside the 1-45-1 panel.

After the couplers were installed, Mr. Robert Burgess provided LAN connections for the Telkonet® Gateway and eXtender®. Engineers ran cat 5e cable from Node 3 on the 01 Level to the Telkonet® Gateway at location 1-45-1 and from Node 6 on the 2nd Deck to the Telkonet® eXtender® in Repair Locker 2. Coaxial cable was then connected between the Gateway and coupler at 1-45-1 and between the eXtender® and coupler in Repair Locker 2 completing the installation (see Figure 3: Ex-USS *Shadwell* Powerline Communications (PLC) Configuration).

Functions of the various Telkonet® components are:

- Gateway - acts as a remotely manageable network switch, which, converts data between a 10/100 Ethernet port and a PLC interface.
- eXtender® - provides additional reach and scalability for network environments that cannot be properly covered by a single Gateway.
- Coupler - passive device through which the Gateway or eXtender® injects the PLC signal into the AC Power infrastructure.
- iBridge® - an intelligent Ethernet to PLC device allowing an AC outlet to function as a LAN drop. Each iBridge® communicates with the Telkonet® Gateway and/or eXtender® using an AES 256-bit encrypted data stream.

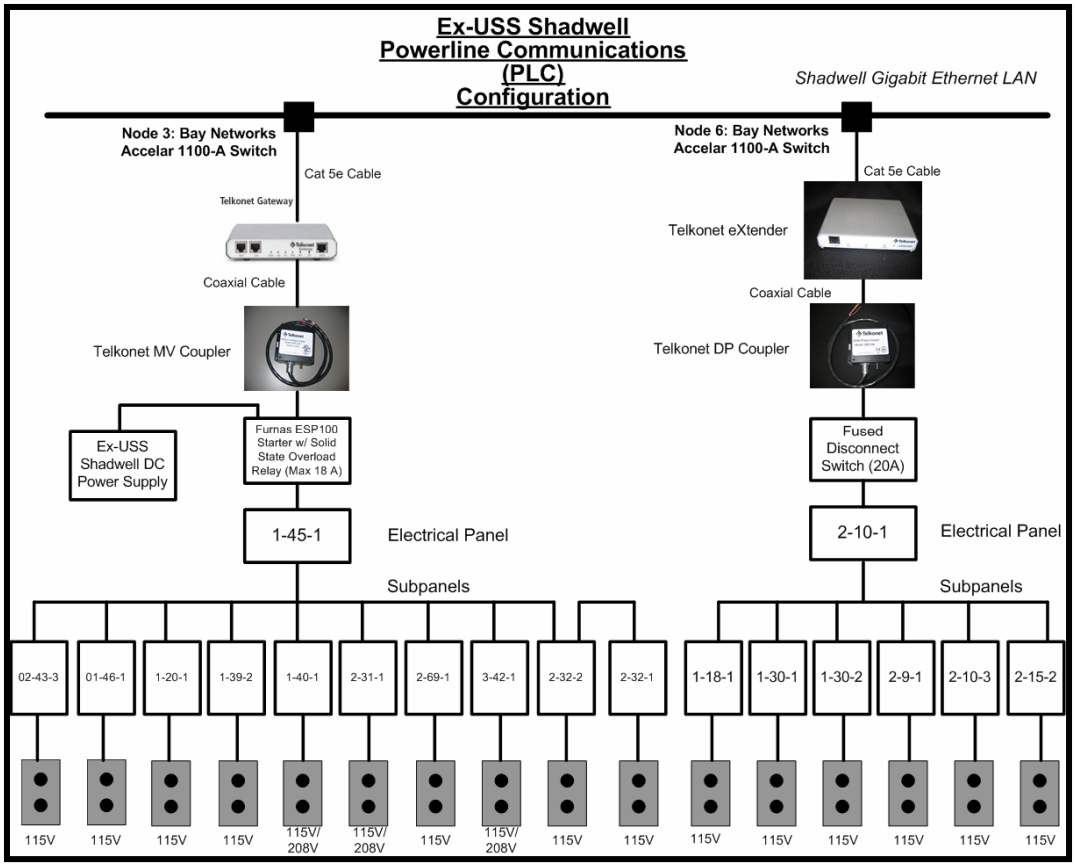

Figure 3 – Ex-USS *Shadwell* Powerline Communications Configuration

The Model 1 SPP is reconfigured to Model 2 by the addition of wireless audio transmitter #2, (operating on Channel 2) which receives an audio input from an additional tap on the audio transformer. This design allows vocals from the SPP circuit to be received by wireless audio receiver #2, (also operating on Channel 2) and worn by the user. This configuration is designated Model 2.

Performance testing for the Model 2 SPP prototype was conducted among several SPP nodes, (Please refer to SPP Node Assignment and Signal Quality Spreadsheet located in Appendix E which assigns sequential numbers to ex-USS *Shadwell's* SPP nodes) limited to jack box outlets (26) in Repair Locker 2 at location 2-9-1, an X40J jack box (22) on the main deck at location 1-12-1, and a male/female hanging dongle (24) at location 2-13-1. A hardwired SPP handset on callbox location 01-48-2 (2), just inside the mess deck entry-way from the weather deck, was used as a monitoring station, as there was generally some ambient noise there at all times. A duplex jack box with one head/chest set connected in "DC Central", location 01-45-1, was a relatively quiet station, and was also used to take DC electrical resistance measurements of that SPP circuit, while the Model 3 interface was connected in Repair 2.

During these SPP tests, watertight doors remained closed, as simultaneous testing of wireless LAN coverage was in progress. This provided a worst-case scenario for the wireless audio links in the test interface. With the interface connected in Repair 2, and Kenney McCombs monitoring reception from node (24) using a handset, it was possible to maintain communications while climbing a ladder that leads to the forecastle from the vicinity of Repair 2 near frame 11, and after passing through and dogging the watertight door. A bi-directional link was maintained while roaming toward the stern, along the starboard side until reaching approximately frame number 26, near the rail. During the first test, a noise-canceling electret microphone (Plantronics® SR1) was used for the interface. This provided good quality voice, but was plagued by severe wind noise when roaming. For a comparison, a throat microphone was used in place of the headset, and the test was repeated, with a microphone output control setting of 500. Since, according to this particular manufacturer (Dynalec® Corporation), the "standard" SPP element has an optimum frequency response centered around 1200 Hz, the received vocal quality was not reduced, but wind noise was eliminated. In both instances, the radio link dropped the session near compartment 01-48-2-L, and resumed when roaming back in the direction of the watertight door previously passed through. Legacy applications of the particular transmitter/receiver pairs used here had allowed good line-of-sight operation out to approximately 200 feet (the manufacturer claims 250 feet), outdoors and with no nearby structures. It had been found that the maximum range was reduced if the transmission path was blocked by either operator of the units. The manufacturer specifications assume that a lapel microphone is used, while its cord doubles as an antenna. This could account for reduced performance, in some instances. The two VHF band FM channels provided by these devices are 169.445MHz and 170.245MHz. In this application, at this stage of development, more emphasis was placed on analyzing the resulting degree of voice fidelity and loudness exhibited by using these radios in the interface, rather than on achieving maximum wireless range.

With assistance from the ship's force monitoring voice quality using the handset at the (2) callbox station, the interface was connected to one of the two SPP jacks (1) in DC Central, with a head/chest-set connected to the second jack. A wireless session was first established using the same electret noise-canceling microphone as in the above tests and quality was subjectively assessed. The same throat microphone used previously was then substituted, with the general observation made that there was "no difference" between the two vocals.

The Pelican® "suitcase" is large enough to contain both Model 1 and Model 2 components. When operating the transmitter/receiver pairs on different channels, and combined with a MOC, the configuration is designated as Model 3. This configuration allows the user to connect to a SPP jack and standoff at some distance while maintaining full-duplex communication with other SPP talkers on that line. This design allows easy substitution of radios and microphones for developmental purposes, and can be operated over the length of any necessary extension SPP cable. Of course, roaming distance for the user is limited by the performance of the two separate wireless audio links, and there is a possibility that either side of the conversation could drop out, leaving the other functioning. Total operation has been shown

to resume if the user relocates. Rather than presenting a gradual decrease in performance to the point of marginal usefulness, full (average) volume is generally maintained by this arrangement for either side of the conversation until one of the radio links drops. A location or particular orientation of the user and the devices will create a situation that allows background noises and occasional "static-like" events to cause the vocal to become difficult to interpret. If the severity of this state of operation is allowed to continue, the point of dropping the RF link can be judged to be close to occurrence.

An obvious improvement upon this method would involve a substitution of the discreet audio transmitter/receiver pairs with an integrated commercial transceiver module.

A provision for more channels would allow Comm Cases to act as stand-alone units or to be grouped in sub-nets, according to immediate needs. Direct communication between Cases (without the use of ship's circuits) would also be feasible. With these potential features in mind, research was focused on a replacement for the Azden® units then in use.

6.3 Equipment Installation

AP Placement

Based upon the recommendations from the Work Plan Two Report, further discussions were held between NRL, *MTS Technologies, Inc.*, and L. Robert Kimball & Associates engineers, and the following final recommendations were subsequently implemented in ex-USS *Shadwell* prior to the FNC team's August 2006 [8] trip to ex-USS *Shadwell*.

01-Level

- Add new AP on forward face of aft bulkhead at approximately 01-36-3. Add 2.4 GHz antenna to 802.11b/g card and mount on NEMA enclosure.
- Add new AP in Damage Control Central on starboard bulkhead at approximately 01-49-0. Add 2.4 GHz antenna to 802.11b/g card and mount on NEMA enclosure.
- Add new AP in storage room (aft of future fire compartment) on inner bulkhead at approximately 01-23-3. Add 2.4 GHz antenna to 802.11b/g card and mount on NEMA enclosure.

01 Level Totals: Add 3 new AP's.

Main Deck

- Add new AP on forward side of bulkhead at 1-29-3, as close as possible to amidships. Add 2.4 GHz antenna to 802.11b/g card and mount on NEMA enclosure.

Main Deck Totals: Add 1 new AP.

2nd Deck

- Add new AP near platform at 2-29-0. Add 2.4 GHz antenna to 802.11b/g card and mount on NEMA enclosure.
- Add new AP near ladder amidships at frame 17. Add 2.4 GHz antenna to 802.11b/g card and mount on NEMA enclosure.
- Move AP 2-18-2 to inner bulkhead of port passageway at approximately frame 20. Add 2.4 GHz antenna to 802.11b/g card and mount on NEMA enclosure.

2nd Deck Totals: Add 2 new AP's

Move 1 Existing AP

3rd Deck

- Move AP 3-15-2 to inner bulkhead 3-17-2.
- Move AP 3-24-2 to inner bulkhead of same compartment. Add 2.4 GHz antenna to 802.11b/g card and mount on NEMA enclosure.
- Move AP 3-29-1 to inner bulkhead near frame 29. Add 2.4 GHz antenna to 802.11b/g card and mount on NEMA enclosure.
- Move AP 3-22-1 to inner bulkhead of same compartment. Add 2.4 GHz antenna to 802.11b/g card and mount on NEMA enclosure.
- Move AP 3-15-1 to inner bulkhead amidships at 3-15-0. Add 2.4 GHz antenna to 802.11b/g card and mount on NEMA enclosure.
- Remove AP 3-29-2 because of the AP being added on platform in open area.

3rd Deck Totals: Add 0 new AP's

Move 5 existing AP's

Remove 1 AP

4th Deck

- Add an AP in the Observation Room. Add 2.4 GHz antenna to 802.11b/g card and mount internal to NEMA enclosure.
- Move the AP in the compartment adjacent to starboard to the inner bulkhead. Add 2.4 GHz antenna to 802.11b/g card and mount internal to NEMA enclosure.

4th Deck Totals: Add 1 New AP

Move 1 Existing AP

5th Deck

- 4th Deck Recommendations suffice for 5th Deck as well.

5th Deck Totals: No Change

6.4 Final Communications Coverage

6.4.1 Prototype Test One – 7-11 Aug 2006

Because a number of APs had been added, moved, or removed since the last ship visit in March 2006, engineers re-evaluated the WLAN coverage by conducting an informal subjective VoIP call procedure after material condition ZEBRA had been set in the Test Area.

The engineers used the Proxim® "Scan Tool" utility to scan ex-USS *Shadwell*'s WLAN for access points. During this period of testing, occasionally the ship's diesel generators went offline, with resulting interruptions in electric power. Subsequently, several access points failed to come back online after these power losses. Engineers examined the "dark" access points and found that some of the Netgear® switches internal to the AP enclosures did not power-up after the power was restored. After Engineers cycled the switch on the Tripp-Lite® outlet strip in the AP enclosure, power was restored to the Netgear® switch.

The Test Team conducted two types of voice quality testing. The first was a "Subjective VoIP Call Evaluation" in which two team members communicated using VoIP endpoints and subjectively evaluated the voice quality. The second was an "Objective Voice Quality Testing & Analysis" in which engineers transmitted a predefined voice file (Reference Voice File) between endpoints. At the receiving endpoint, Engineers saved the received file (referred to as a "Degraded Voice File") to disk for later analysis. See Appendix C for Test Results from Test Plan One Report [4].

Subjective Voice Quality Testing

The VoIP Team conducted a subjective evaluation of voice quality on the wireless network using a "Local Endpoint" (a wired Zultys® Zip 4x5 phone in Repair Locker 2) and a "Remote Endpoint" (a wireless Symbol MC70 PDA running SJ Labs' SJPhone® Softphone).

One team member (referred to as the Local Endpoint team member) remained in Repair Locker 2. Another team member (referred to as the Remote Endpoint team member) took the remote endpoint and began to move through the test area in a proscribed manner, pausing in areas defined as "areas of concern" (Work Plan Two Report, pages 13-18) [5][10][11][12][13].

The Test Area included the 01 level forward of frame 50, Main, 2nd, 3rd, 4th and 5th decks forward of frame 29. The Remote Endpoint team member began the evaluation from the 5th deck, starting in the aft-most compartment and moving forward. While on each deck/level, the Remote Endpoint team member roamed throughout the entire deck/level and kept an active VoIP call to the Local Endpoint team member. After completing a level, the Remote Endpoint team member would proceed to the next deck. The Remote Endpoint team member stopped at each "area of concern," where he took readings of signal strength and the access point through which his device communicated. The two members continuously monitored voice quality throughout the test.

The Response Team initiated a call from the MC70 to the Repair Locker 2 ZIP 4x5 by dialing the extension number of the destination endpoint. The Repair Team answered the call on the destination endpoint ZIP 4X5. The Response Team and Repair Team communicated by reading a predefined series of words to each other, while mutually evaluating the voice quality of the call. The words used were taken from the list in Appendix C and are derived from the ANSI S3.2 intelligibility-testing document. The participating team members assigned the call a score between 1 and 5 (where 1 = bad, 2 = poor, 3 = fair, 4 = good, and 5 = excellent). The analyst entered the members' subjective call scores into the appropriate box on the Subjective VoIP Call Evaluation Score Sheet [10][12].

Engineers rated the overall performance of their VoIP WLAN conversations as "good," with an average subjective MOS rating of 4.06 out of a possible 5.0. Data values are found in Test Plan One Report (see the Subjective VoIP Call Evaluation Score Sheet)[4]. On every call, voice quality was loud and clear, and there were no issues with intelligibility. The reason that most calls were not graded a perfect 5, as opposed to a very good 4, was because there was a slight background hum on the MC70 on most calls, and there was occasionally a slight echo on the ZIP 4x5 phone when talking to an MC70. There was no echo in the MC70. Call quality, as it stands, is very good, and well into the acceptable range. The background hum and slight echo can often times not be heard in the presence of the usual ambient noise.

Objective Voice Quality Testing

For the Objective Voice Quality Testing, the Response Team had an Itronix® tablet PC running GL Communications' Automated File Transceiver (AFT) software connected to a GL Communications' Universal Telephony Adapter (UTA), which in turn was connected to the headset jack of the MC70. Engineers transmitted a Reference Voice File between the two endpoints (Response Compartment and Repair Locker) and recorded a Degraded Voice File (the voice file as it as received) at the endpoint. Engineers saved the degraded voice file to disk to facilitate post event analysis using GL Communications®' VQT Analysis software.

While the Response Team member and the Repair Team member were engaged in an active VoIP call over the PLC network (the MC70 being associated with the Communications Case AP-4000 access point), the Response Team member "roamed" away from the Communications Case (or the Communications Case was powered off). This forced the MC70 to associate with the nearest ex-USS *Shadwell* AP.

Walkthrough Coverage Check

The Response Team and Repair Team conducted a wireless evaluation walkthrough using a Vocera® Communications badge and a Symbol® MC70 as wireless Remote Endpoints and a Zultys® Zip 4x5 in DC Central as the Local Endpoint.

At previously determined "areas of concern," the VoIP team recorded the signal strength at the wireless endpoint as well as the access point to which the wireless endpoint was connected by using the Wireless Companion utility on the MC70. Engineers made annotations on deck diagrams indicating AP association and signal strength in former "areas of concern."

Based on the walkthrough evaluation, engineers determined that all of the "areas of concern" identified on previous visits to ex-USS *Shadwell*, and noted in the Work Plan 2 Report [5], have adequate coverage to make and maintain a good quality voice calls over the wireless LAN under conditions such as those present at the time of the walkthrough.

6.4.2 Prototype Test Two 18-22 September 2006

During Test Two in September 2006 [2], engineers conducted another complete passive 802.11 b/g RF survey in the test area. Engineers collected data points in each accessible compartment to ensure adequate mapping coverage through the test area. Engineers performed various communications testing activities during the visit to the ex-USS *Shadwell* in September 2006 that:

- Subjectively determined the intelligibility of the information transmitted in accordance with ANSI intelligibility standards and
- Objectively determined the intelligibility of data transmitted over two of the three paths of the DC Communications Triad.

Engineers performed throughput testing during three separate fire events. The purpose was to determine what effects fire and smoke might have on the wireless 802.11g signal. The goal was to measure total throughput data and evaluate signal strength and noise intensity measurements prior to and during a fire event. Upon reviewing the data for all the fire events, although there was some standard deviation of the signal during the test period, there was no significant degradation or attenuation of the signal strength or any observed increase in background noise. Detailed results are available in the Future Naval Concepts – Crew Reductions through Improved Damage Control Communications (FNC-CRIDCC) Ex-USS *Shadwell* Triad Test 2 Report (18-22 Sep 2006) [2].

Engineers evaluated the ability of the equipment to provide voice and data communications over the VoIP and PLC paths of the DC Communications Triad. Engineers evaluated the three-way conference call capability of the Triad prototype in the following tests:

- Wireless to Wired VoIP Conference Call: where engineers established a three-way conference call, using one wireless endpoint and two wired endpoints, and were able to communicate with one another with good voice quality.

- Wireless-to-Wireless VoIP Conference Call: where three engineers located in separate locations, equipped with MC70 PDA running SJPhones®, initiated and answered calls in conference mode and were able to communicate with very good voice quality.

- Wireless Sound Powered Phone (SPP) circuit Conference Call: where three engineers, located in separate locations, initiated a three-way SPP conference call where the consensus of the conversation indicated good fidelity and volume.

6.4.3 Test Two Conclusions

- Survey maps and voice testing during the Fire Events indicate that WLAN coverage is excellent in the Test Area, and that the access point placement changes have enhanced the coverage from its original coverage condition (as documented in Work Reports 1 and 2 from FNC work trips to ex-USS *Shadwell* in February and March 2006) to its current state [4][5].

- WLAN coverage in ex-USS *Shadwell* forward of frame 29 is sufficient to support VoIP and PLC/WLAN communications during Fire Events.

- Further testing could resolve VoIP/PLC connectivity during water mist employment and RF/EM interference generated by the unshielded Water mist pumps in ex-USS *Shadwell*

- The Triad concept has been proven successful in minimal Fire Event testing with communications over all three paths of the Triad prototype during Fire Events.

- Wireless interface to SPP circuits did not suffer any noticeable degradation by proximity to the Fire Events.

- Engineers demonstrated that the Triad prototype could successfully communicate over PLC separate and apart from the ex-USS *Shadwell* LAN. The ship's LAN can be down and Communications Case to Communications Case communications are still possible over Telkonet® configured power line circuits

- It is possible to conduct three-person conference calls in the following scenarios: Wireless to Wired VoIP, Wireless-to-Wireless VoIP, and over SPP.

6.4.4 Test Two Recommendations

- Assign unique/specific channels to each access point in ex-USS *Shadwell*. At several locations in the ex-USS *Shadwell*, one AP is located close to another AP. Although each APs placement is necessary to provide a useable level of wireless signal coverage throughout the Test Area, close proximity creates a greater potential for co-channel interference. To minimize the potential for co-channel interference, we recommend that NRL assign each AP in the ex-USS *Shadwell* to a specific, non-conflicting, channel. This will remove the possibility that two APs in close proximity to each other will self-assign to conflicting channels. In addition, assigning permanent channels to APs will eliminate the possibility that an AP will

change its channel while in use, which could interrupt or negatively effect ongoing voice communications.

- Harden the Team Leader device. More engineering work is required in hardening the Team Leader device (Symbol® PC70 PDA), specifically wiring and audio connectors.
- Make the SPP portion of the developmental Communications Cases employed in the testing more rugged.
- Conduct additional prototype testing
  - In water mist environment to check effects of water mist on VoIP/ wireless pathways and determine effects of unshielded water mist pumps on ex-USS *Shadwell* WLAN
  - In larger fires to determine RF interference created by worst-case scenario fires
- Explore expanded capability for the prototype device.

6.5 Triad Communications Prototype Capability

Because of the extensive research and development process, the final prototype [8][9] capability includes software and hardware components, which provide a wireless voice and text messaging communications capability utilizing the ex-USS *Shadwell* WLAN and AC Power lines[1]. In addition, a wireless interface to the ship's Sound Powered Phone (SPP) network is provided.

The prototype capability has the following characteristics:

- Wireless Voice over Internet Protocol (VoIP) communications over the WLAN
- Wireless VoIP communications to the Powerline Communications (PLC) network
- Wireless Voice Interface to the Sound Powered Phone network
- Wireless Text Messaging capability
- Voice over Internet Protocol (VoIP) Communications using VoIP telephones connected to the ship's LAN via Ethernet Cat 5 cables
- Power Line Communications (PLC) are provided through the ex-USS *Shadwell's* standard 115 VAC outlets in the test area
- Two integrated VoIP systems for backup, redundancy and additional capabilities
- Optional speech recognition interface with Vocera® VoIP communications

[1] The ex-USS *Shadwell* (LSD 15) was commissioned in 1943 and built with DC power, AC power being added during her service life, hence the distinction.

- Communications coverage from frame 29 and forward on the 5th, 4th, 3rd, 2nd, and main decks and forward of frame 50 on the 01 Level
- Expandable for future needs
- Utilizes readily available, Commercial Off-The-Shelf (COTS) Products

6.6 Prototype Capability Specific Equipment

The triad communications prototype capability consists of the following major components:

6.6.1 Hardware Components

- Zultys® MX250 VoIP server
- Vocera® VoIP server (Dell® Poweredge 1800 Server)
- Symbol® MC70 PDA used for Voice and Text Communications
- Vocera® Badge used for Voice Communications
- Itronix® Duo-Touch Pen Tablet Computer used for Text Messaging
- Zultys® 4X5 VoIP Telephone
- Telkonet® Gateway for PLC
- Telkonet® Extender for PLC
- Telkonet® iBridge for PLC
- Telkonet® Coupler for PLC
- Disconnect Switch for PLC
- Communications Case (Pelican 1400 Case)
- Proxim® AP-4000 Access Point
- SPP Interface box
- Wiremold 6X952 Five Outlet Power Strip
- LumaPro 30-Foot Retractable Extension Cord Reel
- Azden® 10BT UHF transmitter
- Azden® 100UPR UHF receiver
- Earmark® THR-3 throat microphone

- Pryme® Deluxe Ear Phone EH-189XC
- Plantronics® MX100 Headset
- Panasonic® KX-TCA92 Headset
- Shure® QuietBoom™ Headset

6.6.2 Software Components

- Wildfire® Jabber Server (Server)
- iMov® Messenger client (Symbol MC70 PDA)
- Zultys® MXIE client (Itronix Pentablet)
- SJ Phone (Symbol® MC70 PDA)

Figure 4, illustrates the components of the triad communications prototype capability. A typical communication scenario would include: At the scene of the Primary Damage Area, the Team Leader would be able talk over the WLAN using the Symbol® MC70 PDA to the Repair Locker 2 or DC Central or with any other person with a Symbol® MC70 PDA at any location within the designated test area. This would be accomplished by dialing the appropriate telephone extension from the Symbol® MC70 PDA SJ phone application. The team leader would also be able to plug the communications case into a SPP jack box and an AC receptacle to utilize the other two wireless legs of the communications triad. Use of the communications case provides wireless connectivity with the PLC network over AC electrical wiring. No actions are required by the team leader to switch networks. The wireless Symbol® MC70 PDA will roam to the strongest communications path whether over AC electrical wiring or over the WLAN. The team leader can also utilize the Azden® Radio belt-pack to communicate over the SPP network. As an option, the Vocera® badge can be used as another mobile VoIP phone. The Symbol® MC70 PDA supports text messaging to and from the Itronix® Duo-Touch Pentablets located in the Repair Lockers and DC Central. Users in DC Central or the Repair Lockers can either use the Zultys® 4X5 wired VoIP telephone or the Symbol® MC70 or Vocera® Badge to initiate voice communications. They can also communicate via a standard SPP handset to the team leader using the wireless Azden® Radio SPP interface.

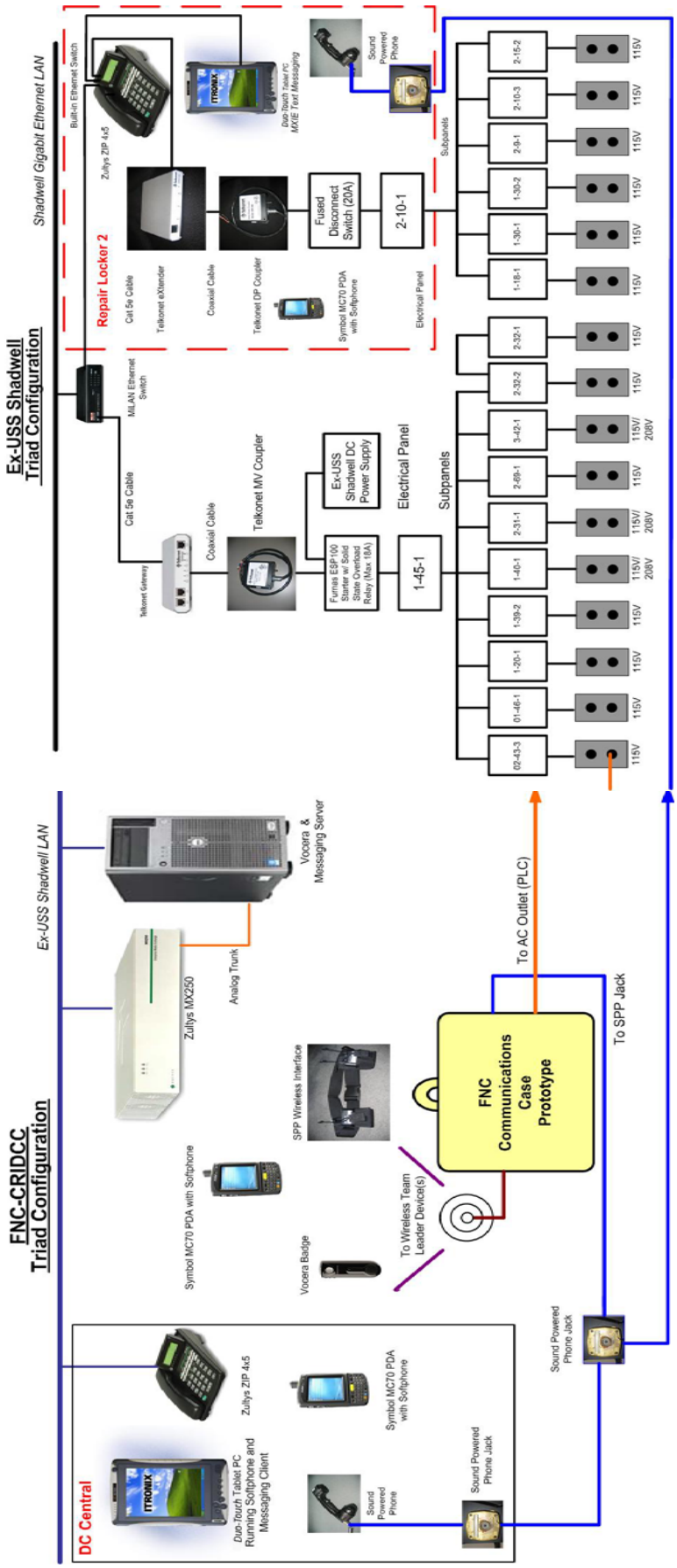

Figure 4 – Triad Prototype System Diagram

6.7 Prototype Delivery and Crew Training

The final prototype configuration was delivered to the ex-USS *Shadwell* (LSD 15) in Mobile, Alabama on 24-25 October 2006. The deliverable included:

- Four communications cases (one each for: Team Leader, DC Central, Repair Locker 1, Repair Locker 2) containing the DC Triad System (VoIP, PLC, SPP)
- Three Itronix® Pentablet Computers for text messaging (one each for: DC Central, Repair Locker 1, Repair Locker 2)
- Four MC-70 PDA's for voice/text messaging
- Zultys® ZIP® VoIP Telephone system
- Vocera® Voice-Activated Badge system (as a secondary VoIP access method)
- A Quick-Start Guide for the prototype capability
- A User's Manual for the prototype capability containing in-depth documentation of the capability and its associated equipment

Approximately seven hours of hands-on training were conducted for designated ex-USS *Shadwell* ship's force personnel onboard, over two days. The training consisted of setting up and verifying functionality of the system aboard ship. The Project Lead gave an overview of the DC Communications Triad capability and concept. Communications Engineers provided guided training on each path of the DC Triad, with its associated equipment.

Ship's Force personnel were guided through the VoIP system components and were trained on making verbal calls using first, the MC-70 hand-held PDA, calling station to station, then the Vocera® Badge system. Ship's force personnel were then trained on integrating the two devices with the Zulty's ZIP® Telephone system, with particular emphasis on interchangeability between all systems. Ship's Force personnel were then trained on sending and receiving text messages between the PDAs and the Pentablets.

Communications Engineers trained Ship's Force personnel on the use of the Powerline Communications (PLC) interface contained in the Communications boxes. This interface allows voice and text transmission, the former interfacing with the installed VoIP system and the latter directly through the ex-USS *Shadwell's* WLAN. Casualty communications procedures were demonstrated using an electric extension cord, similar in concept to electric casualty power cables contained on Fleet ships in the event of a loss of power to the Primary Damage Area (PDA).

Ship's force personnel were trained in the use of the wireless voice interface for the Sound-Powered Telephone (SPP) system. As the "casualty" path of the Triad, the SPP interface has wireless transceivers that are battery powered that provide the minimum 100 dB input sound pressure to "power" the SPP system. In addition, the interface from the communications case to the shipboard circuit was demonstrated as well as a casualty by-pass method (portable sound-powered phone reel).

Lastly, communications engineers demonstrated troubleshooting methods for each path of the Triad as well as the system as a whole. References were identified in the system User's Manual and the Quick-Start Guide and Ship's Force personnel were afforded the opportunity to identify all portable equipment as well as installed equipment by both function and location on the ship.

In addition to copies of the prototype capability Quick-Start Guide and User's Manual (copies of which are included in the CD attached to this Report), copies of documentation provided by manufacturers for each component of the prototype capability with Ship's Force personnel were also provided.

6.8 Inventory Status and Disposition

Market surveys were on a wide variety of equipment and hundreds of components were purchased for testing and evaluation in the laboratory and aboard ex-USS *Shadwell*.

Each component was assigned an individual inventory tracking number, called an FNC number, and was then labeled with that number.

Over 700 Custody Transfer Cards (CTCs) were created to log and track FNC inventory items. Each CTC contained information such as received date, manufacturer ID, quantity, and FNC number(s). Each CTC contains areas in which to enter information when an item is transferred from one location to another.

The Inventory Spreadsheet (Appendix C), contains a listing of the CTC card numbers, as well as other information pertinent to each inventory item such as date received, item description, status (location), and FNC number(s). The number in parentheses next to "Shadwell" indicates the quantities that are located aboard ex-USS *Shadwell*.

Some components (such as connectors, wire, etc.) were integrated into larger subsystems (such as the FNC Comm Cases) and others were utilized "as is." Components that were selected for the Prototype were delivered to ex-USS *Shadwell*. Upon delivery, authorized personnel signed for these components, and their status was updated accordingly on the Inventory Spreadsheet.

7.0 Program Conclusions

The FNC-CRIDCC project proved the concept that a multi-path "Triad" concept is viable for voice and data communications in a shipboard environment. The fire event tests opened the door to expanding use of the prototype from that of solely an "On-Scene leader" communications device to one that may be suitable for use by the response team investigator as well as fire fighting team leaders. Before the prototype is ready for such tasks, it should under go ergonomic adjustments to facilitate compatibility with the fire-fighting ensemble and ruggedization to make

it more resistant to the harsh environment it is likely to encounter during typical shipboard use during damage control events.

7.0 Recommendations

Recommend continuing the development of a prototype "Triad" multi-path communications capability in order to mitigate known and unanticipated effects of a damage control event on the ship's internal casualty communications. Additionally, recommend researching and developing new technologies and equipments as part of this project. First, research and develop equipments and improvements to existing equipments that will "ruggedize" the current prototype for use in a shipboard environment (nominal and battle casualty). Second, assess and develop a device that can add imagery from the Primary Damage Area (PDA) so that a more accurate representation of battle damage can be provided to the Casualty Coordinator and the ship's Commanding Officer. Additionally, the images provided should be significantly robust to allow for transmission to shore or sea-based naval engineers who could provide more accurate repair recommendations that will improve shipboard stability and survivability. Third, the research and development effort should explore technologies that provide personnel location so that casualty response personnel can be more accurately assigned and tracked within the skin of the ship. Improved capabilities will enhance rapid response on ships with reduced crew levels, such as LPD 17, LCS, and DD 1000.

Recommend studying design enhancements such as:

- Leverage research, analysis, and proof of concept conducted during the project to take advantage of new and emerging candidate technologies for Imagery and Personnel Location
- Ruggedize the prototype wireless transceiver interface with the SPP circuit for shipboard use
- Integrate selected imaging, monitoring and locating technologies as an addition to a robust, redundant, and reconfigurable casualty communications capability currently installed in ex-USS *Shadwell* to provide an ongoing demonstration capability
- Test the individual components in both lab and shipboard settings to examine the interaction among current "Triad" prototype capability components and the ex-USS *Shadwell*'s installed systems
- Evaluate the attributes and performance characteristics of the prototype candidate components to determine which candidates best meet the DC communications needs

8.0 References

1. Street, T. T., Williams, F. W., Cooper, S. L., Halloway, K. E. III, et al. “Damage Control Operational Concepts (DCOC): Improved DC Communications”, NRL Ltr Rpt 0399 of 12 September 2005

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3. Carhart, H. W., Toomey, T. A., and Williams, F. W. “The ex-USS SHADWELL Full-Scale Fire Research and Test Ship”, NRL Memo Report 6074 of 6 October 1987, reissued September 1992.

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5. Street, T. T., Williams, F. W., Cooper, S. L., Halloway, K. E. III, Rininger, M., et. al., “Future Naval Concepts – Crew Reductions through Improved Damage Control Communications (FNC-CRIDCC) Work Plan Two for ex-USS SHADWELL Site Visit (6-10 March 2006) NRL Memo Rpt 8973 of 14 July 2006.

6. Street, T. T., Williams, F. W., “Electromagnet Emissions Surveys and RF Transmission Testing Aboard ex-USS SHADWELL” NRL Ltr Rpt 6180/0101 of 13 February 1998.

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8. Street, T. T., “Wireless Spread Spectrum, Low Level RF, DC Communications Network For Repair #2 and The Submarine Mockup Area On ex-USS SHADWELL”, NRL Ltr Rpt 6180/0724.1 of 22 November 1995

9. Street, T. T., Williams, F. W., Cooper, S. L., Halloway, K. E. III, Rininger, M., et al. “Test Plan For The Evaluation of The DC Triad Communications Prototype,” NRL Ltr Report 6180/0321 of 5 September 2006.

10. ANSI S3.2-1989 (American National Standard – Method for Measuring the Intelligibility of Speech over Communications Systems)

11. ANSI S3.5-1997 (American National Standard – Methods for Calculation of The Speech Intelligibility Index)

12. ANSI S3.2-1989 (American National Standard – Method for Measuring the Intelligibility of Speech over Communications Systems)

13. ANSI S3.5-1997 (American National Standard – Methods for Calculation of the Speech Intelligibility Index)

APPENDIX A – SPP Node Assignment and Signal Quality

Approximate Location of SPP Unit	Corresponding SPP Tag Information	Signal Quality	Comments
01 Level			
01-47-0	Unmarked	Active	Located in DC Central
01-48-1	15 INST TR	Active	Monitoring Station; No jack/plug-in
01-40-2	1 JV 14	Active	Located in Sick Bay
01-40-2	2 JZ #3	Inactive	Located in Sick Bay
Main Deck			
1-41-2	Unmarked	Active	Located in passageway
1-41-2	2 JZ 17	Inactive	Located in passageway
1-43-1	1 JV 1-43	Inactive	Located in passageway
1-43-1	2 JZ 16	Inactive	Located in passageway
1-30-1	X 40 J	Active	Located in passageway
1-24-2	1 JV 2	Active	Located in cage area inside Machine Room
1-24-2	1 JV 9	Active	Located in cage area inside Machine Room
1-24-2	Unmarked	Inactive	Located in cage area inside Machine Room
1-25-1	15 INST TR	Active	Monitoring Station; No jack/plug-in; Located on bulkhead inside room
1-25-1	Unmarked	Active	Located on bulkhead inside room
1-25-1	2 JZ #5	Inactive	Located on bulkhead inside room
1-25-1	1 JV-9	Active	Located on bulkhead inside room
1-25-1	1 JV-2	Inactive	Located on bulkhead inside room
1-19-2	1 JV-12	Active	Located in passageway
1-18-1	2 JZ #6	Inactive	Located on bulkhead inside Machine Room
1-18-1	1 JV 26	Active	Located on bulkhead inside Machine Room
1-20-1	1 JV 1-20	Inactive	Located in passageway
1-10-0	X 40 J	Active	Located outside near forward of ship
2nd Deck			
2-22-2	2 JV 15	Inactive	Located on bulkhead inside room
2-14-1	Unmarked	Active	Located on bulkhead inside room
2-12-1	2 JX #6	Inactive	Monitoring Station; Located on bulkhead outside Repair Locker 2
2-10-1	Unmarked	Active	Located on bulkhead inside Repair Locker 2
3rd Deck			
3-17-4	1 JV 12	Inactive	Located on bulkhead inside room
4th Deck			
4-21-4	Call Signal Station Type ICD	Active	Located on bulkhead inside room
5th Deck			

APPENDIX B – Sound Powered Phone Equipment Researched

	SOUND-POWERED PHONE EQUIPMENT RESEARCHED		(Not Purchased)
MANUFACTURER	**MODEL**		**REASON (S) NOT SELECTED**
Hose-McCann Co.	Integrated Wireless Headset		Not a portable base - Complex
	Communications System (IWCS)		Doe not fit with Triad concept
Sound Powered Communicat	SPS-210		Not compatible with shipboard SPP
	SPS-300		Not passive - would introduce voltage to SPP line
Fire House International	SM intercom		Not passive - would introduce voltage to audio line
Aegis	SafetyNet		Radio interconnect unit - Difficult to integrate
Talk-A-Phone	ETP400D		Requires regular telephone or PBX service
EMS Wireless	EkoLink Series		Requires LAN for functionality
			Doe not fit with Triad concept
Harris	RF-6750W Wireless Gateway		Expensive - Requires PC to implement - Complex
Haven Technology Corp.	SC series intercoms		Require AC power - Not compatible with shipboard SI
Gentex	LVIS intercom		Not passive - would introduce voltage to SPP line
Laipac Technology	RF900DV; RF2400DV		Developmental Modules - Difficult to integrate into SPP
Lectrosonics	Wireless Microphone Systems		Expensive - Complex controls
Scott Health and Safety	HAZMAT Radiocom		Powered from separate radio unit - Complex
Dynalec Corp.	LS518 Shipboard Intercom System		Not compatible with shipboard SPP
			Would require use of Lucent Switchboard
			Not passive - would introduce voltage to SPP line
Motorola	CP-150 Shark System		Complex - Hadrware intensive
Flightcom	DC-COM 200 Portable Intercom		VOX-type system - Not compatible with shipboard SI
Wood and Douglas	UHF DUO Transceiver		Requires base station for operation - Complicated interr
			adjustments needed to change microphones

Appendix C - Inventory Status and Disposition

Qty	Product Description	Rec'd	Status (Quantity)	FNC #	Comments
1	ULINE H-895 Anti-Static Mat 3x5	7/22/05	On Hand	FNC00001	
1	ULINE H-895 Anti-Static Mat 3x5	7/22/05	On Hand	FNC00002	
1	480V/3PH/3.5A Transformer Cased	7/26/05	On Hand	FNC00003	
4	BUD NEMA Die-Cast Aluminum Enclosure AN-1300	7/26/05	Shadwell	FNC00004-07	Integrated with CommCases - Signed for by Arthur Durkin
4	BUD NEMA Die-Cast Aluminum Enclosure AN-1307	7/26/05	On Hand	FNC00008-11	
2	BUD NEMA Die-Cast Aluminum Enclosure AN-1306	7/26/05	On Hand	FNC00012-13	
1	Electricians Toolkit	7/29/05	On Hand	FNC00014	
4	BUD NEMA Die-Cast Aluminum Enclosure AN-1302	8/1/05	On Hand	FNC00015-18	
2	Electronics Workbench MSM V8 Power Professional	8/2/05	On Hand	FNC00019 & 166	
1	Agilent E3611A DC Power Supply	8/2/05	On Hand	FNC00020	
1	Agilent 33220A 20 MHz Function/Arb. W. Generator	8/2/05	On Hand	FNC00021	
1	Rohde & Schwarz FS300 Spectrum Analyzer	8/2/05	On Hand	FNC00022	
1	Agilent E3649A Power Supply	8/2/05	On Hand	FNC00023	
1	BK Precision Multifunction Waveform Generator	8/2/05	On Hand	FNC00024	
2	Kingston Datapak 5GB PC card HDD	8/3/05	On Hand	FNC00025-26	
8	Synchrotech 512 MB Hi Speed C/F Card 100x	8/3/05	On Hand	FNC00027-34	
10	Silver TSA-Type Lock, Easy Check Lock 462663	8/3/05	Shadwell (2)	FNC00036	6 Locks on hand - 2 lost from TSA Airport - Signed for by Tom St
2	Storm Case IM2950 32x21x13	8/5/05	On Hand	FNC00037-38	
4	Hardigg Footlocker Case 2914-0903 33x18x15	8/5/05	Shadwell (1)	FNC00039-42	FNC00039 on Shadwell - Signed for by Tom Street
1	Scott Modular Workbench 72x28x34	8/5/05	On Hand	FNC00043	
1	Scott Modular Workbench 72x28x34	8/5/05	On Hand	FNC00044	
2	Luxo Wave+Plus Magnifier	8/17/05	On Hand	FNC00045-46	
1	Logicube F-Sonix Handheld Drive Duplicator	8/12/05	On Hand	FNC00047	
1	Fluke 433 Power Quality Analyzer	8/17/05	On Hand	FNC00048	
1	Weller Soldering Station WSD81	8/17/05	On Hand	FNC00049	
1	Weller Soldering Iron WSP 80	8/17/05	On Hand	FNC00050	
9	Weller Soldering Tips - Assortment	8/17/05	On Hand	FNC00051	
1	Weller Control Module WCB 1	8/17/05	On Hand	FNC00052	
1	Symbol MC50 PDA	8/17/05	On Hand	FNC00053	
1	Symbol Docking Cradle CRD5000-1000U	8/17/05	On Hand	FNC00054	
1	Fluke Microscanner Pro 2105014 Cbl verification tool	8/17/05	On Hand	FNC00055	
1	ANYCOM Blue CF-300 Wireless Printer Adapter	8/17/05	Shadwell	FNC00056	Signed for by Tom Street
1	Hyperextender 8-port managed ethernet switch NV-800E	8/17/05	On Hand	FNC00057	
1	NETSYS Hyperextender plus NV-200LE,200E kit	8/17/05	On Hand	FNC00058-59	
4	Pelican 1400 Case - Silver	8/10/05	On Hand	FNC00060-63	
2	Tripp Lite Isobar 8 Ultra Transient Volt. Surge Suppressor	8/12/05	On Hand	FNC00064-65	
2	Scott Steel Double Door Storage Cabinet 76224A	8/10/05	On Hand	FNC00066-67	
2	Echo Digital Audio Indigo I/O Audio Card	8/12/05	On Hand	FNC00068-69	
1	Scott Open Welded Steel Shop Desk	8/10/05	On Hand	FNC00070	
8	KEI 65002-004, Panel Jack, UA1076	8/30/05	On Hand	FNC00071-78	
1	KEI A537 Relay	8/30/05	On Hand	FNC00079	
1	KEI G15A Jackbox	8/30/05	On Hand	FNC00080	
1	KEI G15B Jackbox	8/30/05	On Hand	FNC00081	
1	KEI G15C Jackbox	8/30/05	On Hand	FNC00082	
1	KEI 65002-770 Switchbox	8/30/05	On Hand	FNC00083	
1	KEI 702019-366 Switch, Rotary	8/30/05	On Hand	FNC00084	
6	KEI A689 Portable Jack	8/30/05	Shadwell	FNC00085-90	Signed for by Tom Street
4	KEI 702003-315 Handset	8/30/05	On Hand	FNC00091-94	
4	KEI 702003-316 Handset	8/30/05	On Hand	FNC00095-98	
2	KEI H-200/U Head-Chest Set	8/30/05	On Hand	FNC00099-100	
2	KEI H-202/U Head-Chest Set	8/30/05	On Hand	FNC00101-102	
2	KEI UA1614-1 Rec/Tran Element	8/30/05	On Hand	FNC00103-104	
2	KEI 702003-552 Trans. Cordset	8/30/05	On Hand	FNC00105-106	

Qty	Product Description	Rec'd	Status (Quantity)	FNC #	Comments
2	KEI 702003-551 Rec. Cordset	8/30/05	On Hand	FNC00107-108	
4	KEI UA1611-1 Rec. Element	8/30/05	On Hand	FNC00109-112	
4	KEI UA1611-2 Trans. Element	8/30/05	On Hand	FNC00113-116	
4	KEI 702019-267 Call Station	8/30/05	On Hand	FNC00117-120	
1	KEI 702019-785 Cordset 25-foot 1 Jack/1 Plug	8/30/05	Shadwell	FNC00121	Signed for by Arthur Durkin
1	KEI 702019-786 Cordset 50-foot 1 Jack/1 Plug	8/30/05	Shadwell	FNC00122	Signed for by Tom Street
1	KEI 702019-787 Cordset 75 foot 1 Jack/1 Plug	8/30/05	On Hand	FNC00123	
1	KEI 702019-788 Cordset 100 foot 1 Jack/1 Plug	8/30/05	Shadwell	FNC00124	Signed for by Arthur Durkin
1	KEI 702019-960 Cordset 25 foot 2 Jacks	8/30/05	On Hand	FNC00125	
1	KEI 702019-961 Cordset 25 foot 2 Jacks	8/30/05	On Hand	FNC00126	
1	KEI 702019-962 Cordset 25 foot 2 Jacks	8/30/05	On Hand	FNC00127	
1	KEI 702019-963 Cordset 25 foot 2 Jacks	8/30/05	On Hand	FNC00128	
1	KEI 702019-300 Generator (Magneto for Call Box)	8/30/05	Shadwell	FNC00129	Signed for by Tom Street
2	KEI 702020-030 Switch Selector	8/30/05	On Hand	FNC00130-131	
4	Linksys WAPPOE12 Power over ethernet adapter kit	8/30/05	On Hand	FNC00132-135	
4	Linksys WAPPOE Power over ethernet kit	8/30/05	On Hand	FNC00136-139	
1	KEI 61660-100 Amplifier	8/30/05	On Hand	FNC00140	
2	Orinoco 2.4 GHz Diversity Antenna	9/6/05	On Hand	FNC00141-142	
2	Orinoco 2.4 GHz Panel Antenna	9/6/05	On Hand	FNC00143-144	
4	Orinoco 2.4.GHz Omni Antenna	9/1/05	On Hand	FNC00145-148	
1	HP 450CBi Mobile Printer	9/8/05	Shadwell	FNC00149	Signed for by Tom Street
2	SanDisk C/F PC Card Adapter	9/8/05	On Hand	FNC00150-151	
1	Proxim Orinoco AP-4000 802.11a/g Wireless Access Point	9/12/05	Shadwell	FNC00152	Signed for by Arthur Durkin
1	Eclipse PC Cable Tester	9/13/05	On Hand	FNC00153	
1	Laird Cable Tester	9/13/05	On Hand	FNC00154	
2	Linksys powerline ethernet bridge	9/16/05	On Hand	FNC00155-156	
1	AC Power Supply for Symbol MC-50 PDA	9/13/05	On Hand	FNC00157	
4	LINKSYS PowerLine USB Adapter	9/19/05	On Hand	FNC00158-161	
2	LINKSYS PowerLine Ethernet Bridge	9/19/05	On Hand	FNC00162-163	
1	Vocera Lab Demo System and 4 Badges	9/21/05	Shadwell	FNC00164,243-246	Signed for by Arthur Durkin
1	Proxim AP-2000 802.11b/g Wireless Access Point	9/26/05	Shadwell	FNC00165	Signed for by Tom Street
1	Proxim AP-2000 802.11b/g Wireless Access Point	9/27/05	Shadwell	FNC00167	Signed for by Tom Street
2	Linksys Wireless-G Notebook Adapter with SRX	9/27/05	On Hand	FNC00168-169	
2	Linksys Wireless-G Broadband Router with SRX	9/27/05	MTS-VAB(1)	FNC00170-171	FNC171 at MTS VAB - Signed for by N. Cohen
2	Linksys Wireless-G Access Point with SRX	9/27/05	On Hand	FNC00172-173	
1	Linksys Wireless-G Access Point	9/27/05	On Hand	FNC00174	
1	Telkonet PLC Gateway	9/28/05	On Hand	FNC00175	
5	Telkonet PLC iBridge	9/28/05	On Hand	FNC00176-180	
2	Telkonet Three Phase Coupler	9/28/05	Shadwell (1)	FNC00181-182	FNC181 on Shadwell - Signed for by Tom Street
1	Telkonet Misc. Installation Materials	9/28/05	On Hand	FNC00183	
1	Linksys Wireless-G Access Point with SRX	9/29/05	On Hand	FNC00184	
1	Telkonet IBMU Software and Documentation	9/30/05	On Hand	FNC00185	
1	Dell PowerConnect 2716 16-Port Switch	9/30/05	On Hand	FNC00186	
3	Orinoco 11b Gold PCI Adapter	8/30/05	On Hand	FNC00187-189	
1	Dell Poweredge 1800 Server	10/7/05	On Hand	FNC00190	
1	Dell 15" Monitor	10/7/05	On Hand	FNC00191	
1	Dell Keyboard	10/7/05	On Hand	FNC00192	
1	Dell Optical Mouse	10/7/05	On Hand	FNC00193	
1	Assorted CAT5e Cables	10/7/05	On Hand	FNC00194	
1	Resistance Decade Box	10/6/05	On Hand	FNC00195	
1	Capacitance Decade Box	10/6/05	On Hand	FNC00196	
2	Terminal Block and Busbar Jumper Connectors	10/6/05	On Hand	FNC00197-198	
1	Hook Up Wire Dispenser	10/6/05	On Hand	FNC00199	
1	Milan 5-Port Ethernet Switch	10/6/05	Shadwell	FNC00200	
3	100A Disconnect Switch	10/6/05	On Hand	FNC00201-204	
3	GCFI Plug 3ft Cable	10/6/05	Shadwell (1)	FNC00205-207	Signed for by Tom Street
7	20 Ohm Enamel Resistor	10/6/05	On Hand	FNC00208-214	
14	D-Sub Gender Changer	10/6/05	On Hand	FNC00215-228	

Qty	Product Description	Rec'd	Status (Quantity)	FNC #	Comments
1	Intel Dialogic 12-Port Analog Trunk Card	10/18/05	On Hand	FNC00229	
4	RG213 RF Cable 5ft	10/26/05	On Hand	FNC00230-233	
3	50 OHM Terminator	10/26/05	On Hand	FNC00234-236	
2	RG213 RF Cable 50ft	10/26/05	On Hand	FNC00237-238	
1	Zultys MX250 VoIP PBX Base System	10/31/05	On Hand	FNC00239	
2	Zultys ZIP 4x4 SIP Phone with Power Adapter	10/31/05	On Hand	FNC00240-241	
1	Zultys ZIP 4x5 SIP Phone with Power Adapter	11/8/05	On Hand	FNC00242	
4	N-Female to N-Female Adapter for 1/4" Chassis	11/8/05	On Hand	FNC00247-250	
1	HyperGain 2-Way Splitter/Coupler	11/8/05	On Hand	FNC00251	
4	AIProx to N-Male 2.5M WBC100 Cable Assembly	11/8/05	On Hand	FNC00252-255	
1	Zultys BPS12 Backup Power Supply	11/9/05	On Hand	FNC00256	
1	Anritsu MS2721A Spectrum Analyzer	11/16/05	On Hand	FNC00257	
1	Anritsu MS2721A Carrying Case	11/16/05	On Hand	FNC00258	
1	Polycom SoundPoint IP501 SIP Phone	11/30/05	On Hand	FNC00259	
1	Polycom SoundPoint IP600 SIP Phone	11/30/05	On Hand	FNC00260	
1	Simpson Analog AC Voltmeter	12/2/05	On Hand	FNC00261	
1	Simpson Current Transformer	12/2/05	On Hand	FNC00262	
1	Simpson AC Ammeter	12/2/05	On Hand	FNC00263	
5	3M SPB-01 Wire Marker Label Books	12/2/05	On Hand	FNC00264-268	
1	Fluke 190C 200MHz Scopemeter	12/2/05	On Hand	FNC00269	
1	Fluke 27 Multimeter	12/9/05	Shadwell	FNC00270	
1	Simpson 260 Series 8P Multimeter	12/9/05	On Hand	FNC00271	
1	Thermostat -RETURNED; WRONG PART SHIPPED	12/9/05	Returned	FNC00272	
2	Terminal Block (8)	12/9/05	On Hand	FNC00273-274	
1	Duet Executive USB Speakerphone	12/12/05	On Hand	FNC00275	
3	Clarisys i750 USB Phone	12/12/05	Shadwell (1)	FNC00276-278	FNC276 on Shadwell - Signed for by Tom Street
1	Plantronics CS50-USB Headset	12/13/05	On Hand	FNC00279	
5	CP-2501SP-ND 2.5mm Stereo Connector w/ Cover	12/14/05	On Hand	FNC00280	
5	CP-2520-ND 2.5mm Female Mono Connector	12/14/05	On Hand	FNC00281	
5	CP-3506-ND 3.5mm Female Mono Connector	12/14/05	On Hand	FNC00282	
5	CP-3502-ND 3.5mm Male Stereo Connector	12/14/05	On Hand	FNC00283	
5	CP-2521-ND 2.5mm Female Stereo Connector	12/14/05	On Hand	FNC00284	
5	CP-3507-ND 3.5mm Female Stereo Connector	12/14/05	On Hand	FNC00285	
5	CP-254S-ND 6-Foot 4-conductor Cable	12/14/05	On Hand	FNC00286	
5	CP-354S-ND 6-Foot 4-conductor Cable	12/14/05	On Hand	FNC00287	
5	CP-254S-M/M-ND 6-Foot 4-conductor Cable	12/14/05	On Hand	FNC00288	
5	CP-354S-M/M-ND 6-Foot 4-conductor Cable	12/14/05	On Hand	FNC00289	
6	CP-2201-ND 6-foot Cable, 2.5mm Mono	12/14/05	On Hand	FNC00290	
6	CP-2205-ND 6-foot Cable, 3.5mm Mono	12/14/05	On Hand	FNC00291	
6	CP-2204-ND 6-foot Cable, 2.5mm Stereo	12/14/05	On Hand	FNC00292	
6	CP-2208-ND 6-foot Cable, 3.5mm Stereo	12/14/05	On Hand	FNC00293	
1	Diamondware Wi-Fone Soft Client (2 PDA, 2 Desktop)	12/15/05	On Hand	FNC00294	
2	Hitachi-Cable Wireless IP5000 Phone	12/15/05	On Hand	FNC00295-296	
1	BK Precision 875B LCR Meter	12/15/05	On Hand	FNC00297	
1	BlueParrot Bluetooth headset	12/22/05	On Hand	FNC00298	
1	Amrel Rocky Patriot DA4 Rugged PDA	12/30/05	On Hand	FNC00299	
2	Sony Sound Forge 8 Audio Editing Software	1/19/06	On Hand	FNC00300-301	
1	Extension Howler	1/25/06	On Hand	FNC00302	
2	SPP Cordset - Extension Howler and Pocket Telephone	1/25/06	On Hand	FNC00303-304	
2	Pocket Telephone	1/25/06	On Hand	FNC00305-306	
3	Leica DISTO A3 Laser Distance Meter	1/26/06	Shadwell (1)	FNC00307-309	FNC309 on Shadwell - Signed for by Tom Street
1	Leica Large Target Plate	1/26/06	On Hand	FNC00310	
3	Leica Small Target Plate	1/26/06	On Hand	FNC00311-313	
1	Symbol MC50 PDA with NAV Keypad & Holster	1/27/06	On Hand	FNC00314	
2	Symbol MC50 PDA Belt Clip	1/27/06	On Hand	FNC00315-316	
1	Itronix Duo-Touch Tablet PC	1/30/06	On Hand	FNC00317	
1	Amrel Rocky Patriot Tablet PC	1/30/06	On Hand	FNC00318	
3	Pelican SabreLite Pocket Flashlight - Yellow	1/30/06	Shadwell (2)	FNC00319-321	FNC320-321 on Shadwell. Signed for by Tom Street

Qty	Product Description	Rec'd	Status (Quantity)	FNC #	Comments
2	Pelican Sabrelite Pocket Flashlight - Orange	1/30/06	Shadwell(2)	FNC00322-323	Signed for by Arthur Durkin
1	Pelican LaserPro Flashlight	1/30/06	Shadwell	FNC00324	Signed for by Tom Street
1	Air Magnet 5354CB PCMCIA Wireless Card	1/30/06	On Hand	FNC00325	
1	Air Magnet Laptop Analyzer Software	2/1/06	On Hand	FNC00326	
1	Air Magnet Surveyor PRO Software	2/1/06	On Hand	FNC00327	
2	Socket Communications Bluetooth SDIO Card for MC50	2/3/06	On Hand	FNC00328-329	
1	Zultys FXO Option Card for MX250 w/ Dongle Cable	2/3/06	On Hand	FNC00330	
1	Zultys EPS24 Power over Ethernet Switch	2/3/06	On Hand	FNC00331	
2	Vishay Angstrohm MP40 300W Rheostat	2/10/06	On Hand	FNC00332-333	
2	Orinoco Range Extender Antenna	2/15/06	On Hand	FNC00334-335	
1	Sennheiser PX200W Headset	2/15/06	On Hand	FNC00336	
1	SMC 802.11g Wireless USB Adapter	2/15/06	On Hand	FNC00337	
3	Tripp-Lite 8 24 inch Outlet Power Strip	2/15/06	Shadwell(2)	FNC00338-340	FNC339-340 on Shadwell - Signed for by Tom Street
1	Linksys Wireless USB Adapter	2/15/06	On Hand	FNC00341	
2	Linksys Wireless-G Compact Flash Card	2/16/06	On Hand	FNC00342-343	
2	Proxim Orinoco AP-4000 802.11a/g Wireless Access Point	2/16/06	Shadwell(1)	FNC00344-345	FNC344 on Shadwell - Signed for by Arthur Durkin
2	Proxim AP-600b Pigtail Antenna Cable	2/16/06	On Hand	FNC00346-347	
2	Proxim Dual Band Range Extender	2/16/06	On Hand	FNC00348-349	
1	Proxim Orinoco 802.11b Gold PCI Card	2/16/06	On Hand	FNC00350	
2	Proxim Orinoco 802.11a/b/g Gold PCI Card	2/16/06	On Hand	FNC00351-352	
2	D-Link Wireless G USB Adapter	2/16/06	On Hand	FNC00353-354	
1	D-Link 802.11a/g Dualband Wireless Cardbus Adapter	2/16/06	On Hand	FNC00355	
1	Sennheiser pc120 3.5mm Headset	2/16/06	On Hand	FNC00356	
1	Plantronics M175 2.5mm Headset	2/16/06	On Hand	FNC00357	
1	Plantronics MX505 2.5mm Headset	2/16/06	On Hand	FNC00358	
1	Plantronics MX150 2.5mm Headset	2/16/06	On Hand	FNC00359	
5	Dymo 19mmx5.5mm Polyester Labels	2/16/06	Consumed	FNC00360-364	
1	16-Pack Maxell Gold C Batteries	2/16/06	Consumed	FNC00365	
2	Tripp-Lite Isobar Ultra 8-Outlet Surge Suppressor	2/16/06	On Hand	FNC00366-367	
2	Tripp-Lite Isobar Ultra 6-Outlet Surge Suppressor	2/16/06	On Hand	FNC00368-369	
1	Tripp-Lite Isotel 6-Outlet Surge Suppressor w/ Modem/Fax	2/16/06	On Hand	FNC00370	
1	D-Link AirPremier 2.4 GHz AP with PoE	2/16/06	On Hand	FNC00371	
1	ASUS WL-530G Pocket 4-Port Router	2/16/06	On Hand	FNC00372	
2	Proxim AP-2000 802.11b/g Wireless Access Point	2/17/06	On Hand	FNC00373-374	
1	SMC EliteConnect 802.11a/b/g Wireless Access Point	2/17/06	On Hand	FNC00375	
2	SMC EliteConnect 802.11a/b/g Wireless Cardbus Adapter	2/17/06	On Hand	FNC00376-377	
1	D-Link Wireless 108G Router	2/17/06	On Hand	FNC00378	
1	16-Pack Maxell Gold D Batteries	2/17/06	Consumed	FNC00379	
1	SMC 802.11g Wireless Broadband Router	2/17/06	On Hand	FNC00380	
1	Proxim 2.4 GHz 9.5dBi Window Antenna	2/17/06	On Hand	FNC00381	
2	Proxim 5 GHz Panel Directional Antenna	2/17/06	On Hand	FNC00382-383	
1	Plantronics MX100 2.5mm Headset	2/20/06	On Hand	FNC00384	
1	Linksys Wireless USB Adapter	2/20/06	On Hand	FNC00385	
1	Plantronics MX205 2.5mm Headset	2/20/06	On Hand	FNC00386	
1	Proxim 5GHz 7dBi Panel Antenna	2/20/06	On Hand	FNC00387	
1	20-Pack Plastic PC Card Cases	2/20/06	On Hand	FNC00388	
1	Black Box Dual Speed 8-Port Mini Hub	2/20/06	On Hand	FNC00389	
1	Plantronics M220C Headset	2/21/06	On Hand	FNC00390	
1	Jabra EarWave Bud Headset	2/21/06	On Hand	FNC00391	
1	SMC 802.11b/g Wireless USB Adapter	2/21/06	On Hand	FNC00392	
1	12-Pack 9V Batteries	2/21/06	Consumed	FNC00393	
1	24-Pack Maxell AAA Batteries	2/16/06	Consumed	FNC00394	
7	Tripp-Lite Isobar Ultra 6-Outlet Surge Suppressor	2/23/06	Shadwell (5)	FNC00395-401	FNC395-398 on Shadwell - Signed for by Tom Street
7	Netgear GS105 5-Port Gigabit Switch	2/23/06	Shadwell (5)	FNC00402-408	FNC404-408 on Shadwell - Signed for by Tom Street
3	Proxim AP-2000 802.11b/g Wireless Access Point	2/23/06	Shadwell (3)	FNC00409-411	Signed for by Tom Street
1	Cushcraft 5 Ghz Antenna	2/23/06	On Hand	FNC00412	
4	DC Telephone Hybrid Transformer	2/23/06	On Hand	FNC00413-416	Integrated into SPP models 1 & 2 (On hand)
4	Audio Center-Tap Transformer	2/23/06	On Hand	FNC00417-420	Integrated into SPP models 1 & 2 (On hand)

Qty	Product Description	Rec'd	Status (Quantity)	FNC #	Comments
1	Cable Ties - 1000 Pack	2/23/06	On Hand	FNC00421	
1	Connector Ring Term #4 18-22 AWG - 100 Count	2/23/06	On Hand	FNC00422	
1	Connector Ring Term #10 18-22 AWG - 100 Count	2/23/06	On Hand	FNC00423	
1	Connector Tongue Spade #6 18-22 AWG - 100 Count	2/23/06	On Hand	FNC00424	
1	Connector Tongue Spade #10 18-22 AWG - 100 Count	2/23/06	On Hand	FNC00425	
1	Cable Grip Black 3-8mm - 10 Count	2/23/06	On Hand	FNC00426	Integrated into CommCases - Signed for by Arthur Durkin
1	Cable Grip Black 3-7mm - 10 Count	2/23/06	On Hand	FNC00427	Integrated into CommCases - Signed for by Arthur Durkin
1	Holder Flat Tie w/ Tape - 100 Count	2/23/06	On Hand	FNC00428	
2	Connector Cable Grip Alum .375-.500	2/23/06	On Hand	FNC00429-430	
2	Connector Cable Grip Alum .125-.250	2/23/06	On Hand	FNC00431-432	
1	Adhesive Kwik Klip - 50 Count	2/23/06	On Hand	FNC00433	
1	Symbol Docking Cradle CRD5000-1000U	2/28/06	On Hand	FNC00434	
1	Shure QuietSpot Boom 2.5mm Headset	2/28/06	On Hand	FNC00435	
1	Tripp-Lite Data Line Surge Suppressor	2/28/06	On Hand	FNC00436	
12	Square D Disconnect Switch Box	2/24/06	Shadwell (12)	FNC00437, 1988-1998	Signed for by Tom Street
1	Telkonet Gateway (G3201G)	2/24/06	Shadwell (1)	FNC00438	Signed for by Tom Street
5	Telkonet iBridge (iB8200M)	2/24/06	Shadwell (5)	FNC00439, 1999-2002	Signed for by Tom Street
2	Telkonet eXtender (eX7201)	2/24/06	Shadwell (1)	FNC00440, 2003	FNC440 on Shadwell - Signed for by Tom Street
6	Telkonet Medium Voltage Coupler (MVC100)	2/24/06	Shadwell (6)	FNC00441, 2004-2008	Signed for by Tom Street
36	Buss Fuses	2/24/06	Shadwell (20)	FNC00442	Signed for by Tom Street
1	Coaxial Cable - 1000 Foot Spool	2/24/06	Shadwell (1)	FNC00443	Signed for by Tom Street
6	Telkonet Delta Phase Coupler (DPC100)	2/24/06	Shadwell (6)	FNC00444, 2009-2013	Signed for by Tom Street
1	Telkonet Tool Kit	2/24/06	Shadwell (1)	FNC00445	Signed for by Tom Street
24	Coaxial Connectors	2/24/06	Shadwell (4)	FNC00446, 2014-2036	Signed for by Tom Street
4	Splitter/Combiner 1-2 Way for Telkonet	2/24/06	On Hand	FNC00447, 2037-2039	
4	Splitter/Combiner 1-3 Way for Telkonet	2/24/06	On Hand	FNC00448,2040-2042	
1	Linksys Wireless-G Router	2/24/06	On Hand	FNC00449	
1	Zultys MX250 VoIP PBX Base System	2/28/06	Shadwell	FNC00450	Signed for by Tom Street
4	Zultys ZIP 4x5 SIP Phone with Power Adapter	3/2/06	Shadwell (3)	FNC00451-454	FNC451-453 on Shadwell - Signed for by Tom Street
7	Proxim AP2000 802.11a Upgrade Kit	3/2/06	Shadwell (5)	FNC00455-461	FNC455-459 on Shadwell - Signed for by Tom Street
3	SMC 802.11G Wireless Travelers Kit	3/3/06	On Hand	FNC00462-464	
1	Sennheiser HD580 Headphones	3/3/06	On Hand	FNC00465	
1	Dymo 19mmx5.5mm Metallized Polyester Labels	3/3/06	On Hand	FNC00466	
1	Proxim Orinoco 2.4GHz 14dBi Panel Antenna	3/3/06	On Hand	FNC00467	
2	Zultys FXS Option Card for MX250	3/7/06	On Hand	FNC00468-469	
4	Zultys Dongle Cables	3/7/06	On Hand	FNC00470-473	
1	Sennheiser PX100 Headphones	3/8/06	On Hand	FNC00474	
1	Duracell 24-Pack AAA Batteries	3/8/06	On Hand	FNC00475	
1	Targus Mobile Port Replicator	3/10/06	On Hand	FNC00476	
1	CD/DVD Drive for Itronix Laptop PC	3/10/06	On Hand	FNC00477	
2	Proxim WaveAccess IEEE Pigtail Antenna Cable	3/15/06	On Hand	FNC00478-479	
1	Sennheiser HD280 Headphones	3/22/06	On Hand	FNC00480	
2	Symbol MC70 Cradle/Charger	3/23/06	On Hand	FNC00481-482	
3	7.5 Foot AC Power Cord for Symbol MC70	3/23/06	On Hand	FNC00483-485	
1	Power Supply for Symbol MC70	3/23/06	On Hand	FNC00486	
2	Li-Ion Battery for Symbol MC70	3/23/06	On Hand	FNC00487-488	
1	5-Pack Charger Shims for MC70	3/23/06	On Hand	FNC00489	
1	Netgear USB 2.0 Ethernet Adapter	3/29/06	On Hand	FNC00490	
2	Netgear 1.5M Antenna Cable	3/29/06	On Hand	FNC00491-492	
1	Netgear 108Mbps 802.11g PC Card	3/29/06	On Hand	FNC00493	
1	Netgear 54Mbps 802.11g Wireless Access Point	3/29/06	On Hand	FNC00494	
2	Netgear 54Mbps 802.11g PC Card	3/29/06	On Hand	FNC00495-496	
1	Netgear ProSafe 802.11g Firewall/Router	3/29/06	On Hand	FNC00497	
1	3Com OfficeConnect 802.11g PC Card	3/29/06	On Hand	FNC00498	
1	3Com OfficeConnect 802.11g Wireless Access Point	3/29/06	On Hand	FNC00499	
1	Netgear RangeMax Wireless Router	3/29/06	On Hand	FNC00500	
1	US Robotics 125Mbps 802.11g PC Card	3/29/06	On Hand	FNC00501	
1	US Robotics 125Mbps 802.11g USB Adapter	3/29/06	On Hand	FNC00502	

Qty	Product Description	Rec'd	Status (Quantity)	FNC #	Comments
2	Motorola Talkabout FV500AA Radio	3/29/06	On Hand	FNC00503-504	
2	SanDisk 2.0 GB CF Card	3/29/06	On Hand	FNC00505-506	
2	Netgear 2.4Ghz 9dBi Indoor/Outdoor Omni Antenna	3/29/06	On Hand	FNC00507-508	
2	Verbatim 1.0GB USB Flash Drive	3/29/06	On Hand	FNC00509-510	
1	US Robotics 125 Mbps 802.11g Access Point	3/30/06	On Hand	FNC00511	
1	US Robotics 125 Mbps 802.11g Range Extender	3/30/06	On Hand	FNC00512	
2	Li-Ion Extended Battery for Symbol MC70	3/31/06	On Hand	FNC00513-514	
2	Belt Clip (Rigid Holster) for Symbol MC70	3/31/06	Shadwell(1)	FNC00515-516	FNC0515 on Shadwell - Signed for by Arthur Durkin
1	Netgear ANT2405 5 dBi Omni Antenna	3/31/06	On Hand	FNC00517	
1	Dell Poweredge 1800 Server	4/3/06	Shadwell	FNC00518	Signed for by Tom Street
1	Dell 15" Monitor	4/3/06	Shadwell	FNC00519	Signed for by Tom Street
1	Dell Keyboard	4/3/06	Shadwell	FNC00520	Signed for by Tom Street
1	Netgear ANT2405 5 dBi Omni Antenna	4/3/06	On Hand	FNC00521	
1	Vocera Lab Demo System and 4 Badges	4/4/06	Shadwell	FNC00522-526	Signed for by Tom Street
10	Analog Phone Line 1 - Line 2 Splitter	4/4/06	Shadwell (3)	FNC00527-536	Signed for by Tom Street - Not specifically numbered items
2	Symbol MC70 PDA	4/5/06	On Hand	FNC00537-538	
2	Li-Ion Extended Battery for Symbol MC70	4/5/06	On Hand	FNC00539-540	
4	Vocera Communications Badges	4/5/06	Shadwell	FNC00541-544	Signed for by Tom Street
12	Vocera Extended Battery	4/5/06	On Hand	FNC00545-556	
1	Trigger Handle for Symbol MC70	4/6/06	On Hand	FNC00557	
1	Symbol 4-Bay Battery Charger / USB-Ethernet Cradle	4/10/06	Shadwell	FNC00558	Signed for by Arthur Durkin
1	Vocera 8-Bay Battery Charger	4/10/06	Shadwell	FNC00559	Signed for by Tom Street
10	Vocera Headset-Ready Lanyard	4/10/06	On Hand	FNC00560-569	
2	Vocera Speaker Horn	4/10/06	On Hand	FNC00570-571	
2	Vocera Badge Holster	4/10/06	On Hand	FNC00572-573	
1	Quam Correctional Grade Intercom Door Station	4/11/06	On Hand	FNC00574	
2	110VAC Wall Power Supply	4/11/06	On Hand	FNC00575-576	
1	Backbox for Quam Intercom Door Station	4/11/06	On Hand	FNC00577	
2	Electret Stick-on Microphone 3.5mm	4/11/06	On Hand	FNC00578-579	
1	AIPhone Intercom Door Station	4/11/06	On Hand	FNC00580	
1	Lantronix UBox USB Device Server	4/11/06	On Hand	FNC00581	
1	Bluetooth Installation Signal Range Test Unit - PAIR	4/11/06	On Hand	FNC00582-583	
2	GridConnect Blueplug Bluetooth RS232 Adapter	4/11/06	On Hand	FNC00584, FNC00593	
2	GridConnect Blueplug Bluetooth USB Adapter	4/11/06	On Hand	FNC00585-586	
1	GridConnect Netport RS232 to Ethernet Adapter	4/11/06	On Hand	FNC00587	
2	Contemporary Controls Commercial 5-port Ethernet Switch	4/11/06	On Hand	FNC00588-589	
1	US Robotics 802.11G Max Cable/DSL Router	4/11/06	On Hand	FNC00590	
2	Zultys WIP2 WiFi Phones	4/12/06	On Hand	FNC00591-592	
1	Intel Dialogic 12-Port Analog Trunk Card	4/17/06	Shadwell	FNC00594	Signed for by Tom Street
3	Proxim Orinoco AP-4000 802.11a/g Wireless Access Point	4/24/06	Shadwell	FNC00595-597	FNC595 and FNC597 on Shadwell - Signed for by Arthur Durkin
2	Milan 5-Port Ethernet Switch	4/24/06	On Hand	FNC00598-599	
1	Pelican 1500 Case - Black	4/24/06	On Hand	FNC00600	
3	Netgear 1.5M Antenna Cable	4/24/06	On Hand	FNC00601-603	
1	Netgear 5M Antenna Cable	4/24/06	On Hand	FNC00604	
3	Tripp-Lite 24 in. 8-Outlet Power Strip	4/24/06	On Hand	FNC00605-607	
5	Dymo 19mmx5.5mm Polyester Labels	4/24/06	On Hand	FNC00608-612	
2	Energizer Max AA Batteries - 16 Pack	4/24/06	On Hand	FNC00613-614	
4	Belkin Stanley 4-Outlet Power Strip	4/24/06	On Hand	FNC00615-618	
4	Belkin Stanley 6-Outlet Power Strip	4/24/06	On Hand	FNC00619-622	
4	Belkin Stanley 8-Outlet Power Strip	4/24/06	On Hand	FNC00623-626	
1	Symbol MC70 Vehicle Cradle	4/24/06	On Hand	FNC00627	
1	Pelican 1450/1451 Case Foam Set	4/24/06	On Hand	FNC00628	
2	Milan 8-Port Ethernet Switch	4/25/06	On Hand	FNC00629-630	
3	Netgear ANT2405 5 dBi Omni Antenna	4/25/06	On Hand	FNC00631-633	
1	enGenius DuraFon IX Base Station	4/25/06	On Hand	FNC00634	
2	enGenius DuraFon IX Handset and Charger	4/25/06	On Hand	FNC00635-636	
1	Grandstream HandyTone 286 Analog Telephone Adapter	4/26/06	On Hand	FNC00637	
1	Grandstream HandyTone 486 Analog Telephone Adapter	4/26/06	On Hand	FNC00638	

Qty	Product Description	Rec'd	Status (Quantity)	FNC #	Comments
1	Linksys SPA-1001 Analog Telephone Adapter	4/26/06	On Hand	FNC00639	
1	D-Link DVG-2001S Analog Telephone Adapter	4/26/06	On Hand	FNC00640	
1	Linksys SPA-901 SIP Phone	4/26/06	On Hand	FNC00641	
1	I-Mate JasJar PDA	4/26/06	On Hand	FNC00642	
2	Panasonic KX-TCA92 2.5mm Headset	4/26/06	On Hand	FNC00643-644	
1	VoipSupply.com IP Telephone Power Cube	4/26/06	On Hand	FNC00645	
2	GC-IPIC-ESWX-110 IP Intercom White Wall	4/28/06	On Hand	FNC00646-647	
2	GC-IPIC-EWSTX-110 IP Interecom White Wall	4/28/06	On Hand	FNC00648-649	
1	GC-IPIC-MSTX IP Intercom OEM Board	4/28/06	On Hand	FNC00650	
1	GC-IPIC-EDBX-110 IP Intercom Black Desk	4/28/06	On Hand	FNC00651	
2	Linksys Network Optimizer Gaming/VoIP	4/27/06	On Hand	FNC00652-653	
1	Milan ShAir AccessG Pro AP/Bridge with PoE	4/27/06	On Hand	FNC00654	
1	9500 Fire Mate Glove Large	4/27/06	On Hand	FNC00655	
1	300-2207 Nomex Ultimate Hood	4/27/06	On Hand	FNC00656	
1	Black Nomex/Spandex Gloves Large	4/27/06	On Hand	FNC00657	
1	Black Nomex/Spandex Gloves X-Large	4/27/06	On Hand	FNC00658	
1	300-2257 PBI Ultimate Hood	4/27/06	On Hand	FNC00659	
1	ETEN M600	5/1/06	On Hand	FNC00660	
2	Pelican 1030 Micro Case W/liner Black	5/1/06	On Hand	FNC00661-662	
2	Pelican 1040 Micro Case Black/Clear	5/1/06	On Hand	FNC00663-664	
2	Pelican 1060 Case Black Solid	5/1/06	On Hand	FNC00665-666	
2	Pelican 1020 Micro Case Black/Clear	5/1/06	On Hand	FNC00667-668	
2	Pelican 1010 Micro Case w/liner Black	5/1/06	On Hand	FNC00669-670	
1	Pelican 1490 Watertight NoteBook Case	5/1/06	On Hand	FNC00671	
3	Pelican 1450 Universal Case Adaptive Yellow	5/1/06	On Hand	FNC00672-674	
2	Pelican 1510 Ext Handle Carry on Case	5/1/06	On Hand	FNC00675-676	
1	Pelican 1520 Case w/Foam Silver	5/1/06	On Hand	FNC00677	
1	Voice Quality Testing (VQT) - PESQ Only Software	5/3/06	On Hand	FNC00678	
2	Automated File Transfer (AFT) Software	5/3/06	On Hand	FNC00679-680	
2	Universal Telephony adapter (UTA)	5/3/06	On Hand	FNC00681-682	
2	High Quality USB Audio Capture Unit	5/3/06	On Hand	FNC00683-684	
1	Adobe Audition Multitrack Sound file software	5/3/06	On Hand	FNC00685	
1	Fluke Logging Thermometer	5/4/06	On Hand	FNC00686	
1	FlukeView Forms Software	5/4/06	On Hand	FNC00687	
2	Fluke Tempature Probe Air	5/4/06	On Hand	FNC00688-689	
2	Fluke Thermocouple Extension	5/4/06	On Hand	FNC00690-691	
1	Soft Carrying Case	5/4/06	On Hand	FNC00692	
2	General Purpose Bead Probe	5/4/06	On Hand	FNC00693-694	
6	G15A Single Jack Box	5/4/06	Shadwell	FNC00695-701	Signed for by Tom Street
4	G15B Double Jack Box	5/4/06	Shadwell	FNC00702-705	Signed for by Tom Street
6	UA1000 Plug	5/4/06	Shadwell	FNC00706-711	Signed for by Tom Street
2	WiFi Plus 3dBi MP Bullet Omni Antenna	5/5/06	On Hand	FNC00712-713	
2	5dBi 2.4 Ghz Omni Antenna	5/5/06	On Hand	FNC00714-715	
2	5dBi MP5 Omni Hole Mount	5/5/06	On Hand	FNC00716-717	
2	NM/Lucent/Avaya/Orinoco/ 2ft cable	5/5/06	On Hand	FNC00718-719	
2	400 Cable/ RPTNCM/NM/2ft cable	5/5/06	On Hand	FNC00720-721	
1	Footbolts/Tar Sealers	5/5/06	On Hand	FNC00722	
1	3 Foot Antenna Tripod	5/5/06	On Hand	FNC00723	
1	Antenna Mounting Arm	5/5/06	On Hand	FNC00724	
1	14.5 dBi Antenna/ Circular Polarized/NF	5/5/06	On Hand	FNC00725	
1	10.5 dBi Antenna/ Circular Polarized/NF	5/5/06	On Hand	FNC00726	
1	5 dBi Antenna/ Circular Polarized/NF	5/5/06	On Hand	FNC00727	
3	AlProx to N-Female 19in 100-series Cable	5/8/06	On Hand	FNC00728-730	
3	AlProx to N-Male 19in 100-series Cable	5/8/06	On Hand	FNC00731-733	
3	AlProx to N-Female Bulkhead 19in 100-series Cable	5/8/06	On Hand	FNC00734-736	
3	ALProx to N-Male 1.5m 100-series Cable	5/8/06	On Hand	FNC00737-739	
3	ALProx to N-Make 2.5m 100-series Cable	5/8/06	On Hand	FNC00740-742	
3	SPA900 Series Mounting Bracket	5/8/06	On Hand	FNC00743	

Qty	Product Description	Rec'd	Status (Quantity)	FNC #	Comments
2	Azden 10BT 800MHz BodyPack Transmitter	5/10/06	On Hand	FNC00744-745	Integrated into developmental CommCases (On hand)
2	Azden 100UPR 800MHz Portable Receiver	5/10/06	On Hand	FNC00746-747	Integrated into developmental CommCases (On hand)
2	Azden WM-PRO Transmitter with Lapel Mic	5/10/06	On Hand	FNC00748-749	Integrated into developmental CommCases (On hand)
2	Azden WR-PRO Receiver	5/10/06	On Hand	FNC00750-751	Integrated into developmental CommCases (On hand)
2	Applied Wireless R900AU-EV Audio Receiver Eval Board	5/10/06	On Hand	FNC00752-753	
2	Applied Wireless T900AU-EV Audio Transmitter Eval Board	5/10/06	On Hand	FNC00754-755	
1	GN Netcom Jabra JX10 Bluetooth Headset	5/10/06	On Hand	FNC00756	
1	Motorola HS850 Bluetooth Headset	5/10/06	On Hand	FNC00757	
1	Plantronics Voyager 510SL Bluetooth Headset / Handset Lifter	5/10/06	On Hand	FNC00758	
1	Plantronics CS50 900MHz Wireless Headset / Handset Lifter	5/10/06	On Hand	FNC00759	
1	Plantronics Audio 40 Multimedia Headset	5/10/06	On Hand	FNC00760	
1	GN Netcom GN 6210 Bluetooth Headset Bundle	5/10/06	On Hand	FNC00761	
1	GN Netcom Jabra BT250V Bluetooth Headset	5/10/06	On Hand	FNC00762	
1	GN Netcom GN 9120 MIDI Headset	5/10/06	On Hand	FNC00763	
20	Tripp Lite RJ11 Coupler Female-to-Female	5/10/06	On Hand	FNC00764-783	
1	Bullard PX Firefighter Helmet with Face Shield	5/11/06	On Hand	FNC00784	
1	Bullard PX Firefighter Helmet with Goggle	5/11/06	On Hand	FNC00785	
2	HD Communications AP-4000 Antenna Pigtail Cable	5/11/06	On Hand	FNC00786-787	
1	GN Netcom GN1000 Handset Lifter	5/10/06	On Hand	FNC00788	
1	Linksys WIP330 802.11G Wireless SIP Phone	5/18/06	On Hand	FNC00789	
1	American Firewear 9500 Fire Mate Gloves	5/24/06	On Hand	FNC00790	
1	Steamblock Firewall Fire Gloves	5/24/06	On Hand	FNC00791	
1	Aluminized Fire Pants	5/24/06	On Hand	FNC00792	
1	Aluminized Fire Coat	5/24/06	On Hand	FNC00793	
1	Bullard FXA-1 Firefighter Helmet with Face Shield	5/24/06	On Hand	FNC00794	
1	Plantronics Discovery 640 Bluetooth Headset	5/30/06	On Hand	FNC00795	
1	Itronix Duo-Touch Tablet PC	6/12/06	Shadwell	FNC00796	Signed for by Arthur Durkin
2	Symbol MC70 1X Battery Cover	6/13/06	On Hand	FNC00797-798	
1	Itronix GoBook III Laptop PC	2/17/06	On Hand	FNC00799	
2	Axis 241S Video Server	6/15/06	On Hand	FNC00800-801	
1	Axis 241Q Video Server	6/15/06	On Hand	FNC00802	
1	Axis 206M Network Camera	6/15/06	On Hand	FNC00803	
1	Axis 207 Network Camera	6/15/06	On Hand	FNC00804	
2	Viotac SCOUT Cam	6/15/06	On Hand	FNC00805-806	
1	Viotac Mounting Kit	6/15/06	On Hand	FNC00807	
2	Axis 207W Wireless Network Camera	6/16/06	On Hand	FNC00808-809	
1	Axcess AT132 Activator/Receiver Evaluation Cable Kit	6/16/06	On Hand	FNC00810	
2	Axcess AT132 ActiveTag Activator	6/16/06	On Hand	FNC00811-812	
1	Axcess AT132 ActiveTag Dual Activator	6/16/06	On Hand	FNC00813	
4	Axcess AT132 Network Receiver	6/16/06	On Hand	FNC00814-817	
4	Lantronix UDS-10 (For Axcess)	6/16/06	On Hand	FNC00818-821	
1	Axcess ActiveTrack System Software	6/16/06	On Hand	FNC00822	
2	Axcess Flex Antenna	6/16/06	On Hand	FNC00823-824	
3	Axcess AT132P Personnel Tag	6/16/06	On Hand	FNC00825-827	
3	Axcess Personnel FOB	6/16/06	On Hand	FNC00828-830	
3	Axcess LED Tag	6/16/06	On Hand	FNC00831-833	
3	Axcess Credential Tag	6/16/06	On Hand	FNC00834-836	
3	Axcess LED Diagnostic Tag	6/16/06	On Hand	FNC00837-839	
2	Axcess Acrylic Bar Antenna	6/16/06	On Hand	FNC00840-841	
1	Axcess Drop Ceiling Antenna	6/16/06	On Hand	FNC00842	
3	Proxim AP-2000 802.11b/g Upgrade Kit	6/16/06	Shadwell	FNC00843-845	Signed for by Arthur Durkin
1	Proxim/Orinoco/Lucent AP-2000 (AS-2000) Access Point	6/16/06	On Hand	FNC00846	
25	Ekanau T201 WiFi Locator Tag	6/16/06	On Hand	FNC00847-871	
1	Ekanau C201 24-Bay WiFi Tag Charger	6/16/06	On Hand	FNC00872	
6	Proxim AP-2000 Access Point (No Cards)	6/18/06	Shadwell	FNC00873-878	Signed for by Arthur Durkin
1	Axis Camera Station 1.0 Software	6/19/06	On Hand	FNC00879	
1	Axis Camera Explorer Software	6/19/06	On Hand	FNC00880	
2	Viotac 12V Rechargeable Battery Pack	6/19/06	On Hand	FNC00881-882	

Qty	Product Description	Rec'd	Status (Quantity)	FNC #	Comments
1	Axis 206 Network Camera	6/20/06	On Hand	FNC00883	
1	Axis 2420 Network Camera	6/20/06	On Hand	FNC00884	
2	Belkin 50' Extension Cord	6/20/06	On Hand	FNC00885-886	
2	Belkin 7-Port USB 2.0 Hub	6/20/06	On Hand	FNC00887-888	
17	WiFi Plus 3dBi MP Bullet Omni Antenna	6/20/06	Shadwell	FNC00889-905	Signed for by Arthur Durkin
27	Pigtail 2-Ft Antenna Cable for AP-2000	6/20/06	Shadwell(25)	FNC00906-932	FNC906-930 on Shadwell - Signed for by Arthur Durkin
4	Proxim AP-2000 802.11b/g Upgrade Kit	6/21/06	Tom Street (3)	FNC00933-936	FNC933-935 on Shadwell - Signed for by Arthur Durkin
2	Wire Test Leads 21AWG 22" 5PCS	6/21/06	On Hand	FNC00937-938	
2	12-Pack Energizer Industrial 9V Batteries	6/21/06	Consumed	FNC939-940	
8	Telecom Transformer Dual T1/E1	6/21/06	Shadwell	FNC00941-948	Integrated into CommCases 3-6 - Signed for by Arthur Durkin
1	3M Hook & Loop Adhesive	6/21/06	Shadwell	FNC00949	Integrated into CommCases 3-6 - Signed for by Arthur Durkin
4	Connector Terminal Strip 4 POS 3/8"	6/21/06	On Hand	FNC00950-953	
4	Prototyping Board 4" x 5"	6/21/06	On Hand	FNC00954-957	
10	3.5mm Stereo Cable Extension - 2.5m	6/21/06	On Hand	FNC00958-967	
1	100-Pack Connector Tongue Spade	6/21/06	On Hand	FNC00968	
2	3M Super 33+ Vinyl Electrical Tape	6/21/06	On Hand	FNC00969-970	
1	3M 130C Linerless Rubber Splicing Tape	6/21/06	On Hand	FNC00971	
1	Motorola H500 Bluetooth Headset	6/21/06	On Hand	FNC00972	
1	Audiosoft Frontline Communicator Kit	6/22/06	On Hand	FNC00973	
7	Proxim AP-2000 802.11a Upgrade Kit	6/26/06	Shadwell(6)	FNC00974-980	FNC00974 through FNC00979 on Shadwell - Signed for by Arthu
1	MemoryLink StrongBow STP400A Video Transport System	6/26/06	On Hand	FNC00981-982	
2	Axis 241SA Video Server	6/29/06	On Hand	FNC00983-984	
2	Pelican 1400 Case - Silver	7/6/06	On Hand	FNC00985-986	
2	Pelican 1510 Ext Handle Carry on Case - Black	7/6/06	On Hand	FNC00987-988	
1	Pelican 1450 Case - Orange	7/6/06	On Hand	FNC00989	
3	Pelican 1450 Case - Yellow	7/6/06	On Hand	FNC00990-992	
4	Telkonet iBridge (iB8200M)	7/10/06	Shadwell(2)	FNC00993-996	FNC993 and FNC994 on Shadwell - Signed for by Arthur Durkin
2	Vostek MX-3000 Video Transmitter	7/10/06	On Hand	FNC00997-998	
2	Vostek RMX-3000 Video Receiver	7/10/06	On Hand	FNC00999-1000	
5	Vostek AL-24R Antenna	7/10/06	On Hand	FNC01001-1005	
5	Vostek AX-24R Antenna	7/10/06	On Hand	FNC01006-1010	
2	Vostek AN-24S Antenna	7/10/06	On Hand	FNC01011-1012	
2	Vostek SDX-22 MIL Transmitter (1 Channel 6, 1 Channel 7)	7/10/06	On Hand	FNC01013-1014	
1	Vostek VRX-24L M Receiver	7/10/06	On Hand	FNC01015	
1	Vostek VRX-24L MIL Receiver	7/10/06	On Hand	FNC01016	
1	Vostek VRX-24L Z Receiver	7/10/06	On Hand	FNC01017	
2	Vostek M-808 Receiver	7/10/06	On Hand	FNC01018-1019	
2	Vostek HPX-916 Transmitter	7/10/06	On Hand	FNC01020-1021	
1	Vostek LX-900 Transmitter	7/10/06	On Hand	FNC01022	
2	Vostek RM-900B Receiver	7/10/06	On Hand	FNC01023-1024	
3	Vostek AN-900 Antenna	7/10/06	On Hand	FNC01025-1027	
1	Vostek Power Supply 1A/12V for LX-900	7/10/06	On Hand	FNC01028	
6	Vostek Power Supply 200mA/6V for M-808	7/10/06	On Hand	FNC01029-1034	
1	Vostek VRX-24LTS/M Receiver	7/10/06	On Hand	FNC01035	
6	Black Box 10 Inch Outlet Saver Extension Cord	7/17/06	Shadwell(4)	FNC01036-1041	FNC1036-1039 on Shadwell - Signed for by Arthur Durkin
3	Sennheiser MX500 Earbud Headphones	7/17/06	On Hand	FNC01042-1044	
1	Electrical Plug - Locking	7/17/06	On Hand	FNC01045	
2	Hubbell Marine Electrical Receptacle	7/17/06	Shadwell	FNC01046-1047	Signed for by Tom Street
12	Stainless Steel Duplex Electrical Outlet Cover	7/17/06	Shadwell	FNC1048-1059	Signed for by Tom Street
2	Bell Weatherproof Outlet Cover	7/17/06	Shadwell	FNC01060-1061	Signed for by Tom Street
3	Coiled Power Cord	7/17/06	Shadwell (1)	FNC01062-1064	Signed for by Tom Street
1	Retractable Power Cord	7/17/06	Shadwell	FNC01065	Signed for by Tom Street
2	RTV Silicone Sealant	7/17/06	Shadwell	FNC01066-1067	Signed for by Tom Street
2	5/8 " Flat Washer - 25 Count	7/17/06	Shadwell (1)	FNC01068-1069	Signed for by Tom Street
12	Electrical Box - 13 Cu. In	7/17/06	Shadwell	FNC01070-1081	Signed for by Tom Street
2	Electrical Box - 16 Cu. In	7/17/06	Shadwell	FNC01082-1083	Signed for by Tom Street
6	Blank Electrical Box Cover	7/17/06	Shadwell	FNC01084-1089	Signed for by Tom Street
14	Duplex Outlet Cover	7/17/06	Shadwell	FNC01090-1103	Signed for by Arthur Durkin

Qty	Product Description	Rec'd	Status (Quantity)	FNC #	Comments
24	Electrical Connector - Cable/Cord	7/17/06	Shadwell	FNC01104-1127	Signed for by Tom Street
1	Twist Wire Connector (100 pc)	7/17/06	Shadwell	FNC01128	Signed for by Tom Street
1	Twist-Lock Electrical Plug	7/17/06	Shadwell	FNC01129	Signed for by Tom Street
3	Plug 5-15p NEMA	7/17/06	On Hand	FNC01130-1132	
3	Plug Valise 5-15 NEMA	7/17/06	On Hand	FNC01133-1135	
3	Connector 5-15R NEMA	7/17/06	On Hand	FNC01136-1138	
3	Connector 5-15 NEMA	7/17/06	On Hand	FNC01139-1141	
40	Electrical Receptacle 15 A 125 V	7/18/06	Shadwell	FNC01142-1181	Signed for by Tom Street
2	Astrodyne SPU12A-105 Wallmount Power Supply	7/19/06	On Hand	FNC01182-1183	
2	Astrodyne SPU15A-105 Desktop Power Supply w/ extra cable	7/19/06	On Hand	FNC01184-1185	
2	Astrodyne SPU15B-105 Desktop Power Supply w/ extra cable	7/19/06	On Hand	FNC01186-1187	
2	Zultys SCSI Hard Drives with RAID	7/20/06	On Hand	FNC01188-1189	
1	Scott Health & Safety Air-Pak 50	7/20/06	On Hand	FNC01190	
1	Scott Health & Safety AV-3000	7/20/06	On Hand	FNC01191	
1	100-Pack Insulated Fork Terminal 16-14AWG #8	7/21/06	On Hand	FNC01192	
2	3M Super 33+ Vinyl Electrical Tape	7/21/06	On Hand	FNC01193-1194	
1	HeatShrink Kit	7/21/06	On Hand	FNC01195	
1	3M Copper Foil Tape 1/4" x 18 Yards	7/21/06	On Hand	FNC01196	
8	6-Foot Stereo Extension Cable 2.5mm Male to Female	7/21/06	On Hand	FNC01197-1204	
8	3.5mm Stereo Female to 2.5mm Stereo Male Adapter	7/21/06	On Hand	FNC01205-1212	
2	System Blower Ball Bearing Turbine Fan 42CFM	7/21/06	On Hand	FNC01213-1214	
2	40mm Sunon 12VDC Ball Bearing Fan	7/21/06	On Hand	FNC01215-1216	
2	Vantec Stealth 60mm Double Ball Bearing Silent Case Fan	7/21/06	On Hand	FNC01217-1218	
4	60mm Plastic Fan Guard	7/21/06	On Hand	FNC01219-1222	
4	6 inch 3.5mm Y-Adapter 3.5mm Female to 3.5mm Male x 2	7/21/06	On Hand	FNC01223-1226	
1	1 inch 3.5mm Female-Female Coupler	7/21/06	On Hand	FNC01227	
8	3.5mm Stereo Male to 2.5mm Stereo Female Adapter	7/21/06	On Hand	FNC01228-1235	
2	40mm Chrome Wire Fan Finger Guard	7/21/06	On Hand	FNC01236-1237	
2	60mm Chrome Wire Fan Finger Guard	7/21/06	On Hand	FNC01238-1239	
1	1 inch 3.5mm Male-Male Coupler	7/21/06	On Hand	FNC01240	
1	Sennheiser MX500 Earbud Headphones	7/27/06	On Hand	FNC01241	
10	WiFi Plus 3dBi MP Bullet Omni Antenna	7/28/06	Shadwell(8)	FNC01242-01251	FNC1242-1249 on Shadwell - Signed for by Arthur Durkin
2	Sennheiser PC140 Neck Headset	7/31/06	On Hand	FNC01252-1253	
2	Itronix Duo-Touch Tablet PC	8/1/06	Shadwell	FNC01254-1255	Signed for by Arthur Durkin
12	Pelican 1010 Micro Case Yellow/Clear	8/2/06	On Hand	FNC01256-1267	
5	Pelican 1040 Micro Case Yellow/Clear	8/2/06	Shadwell (2)	FNC01268-1272	FNC01268, FNC01269, FNC01270 on Shadwell - Signed for by A Durkin
1	Pelican 1020 Micro Case Yellow/Clear	8/2/06	On Hand	FNC01273	
1	Air Magnet 5354CB PCMCIA Wireless Card	8/23/06	On Hand	FNC01274	
1	Air Magnet Laptop Analyzer Software	8/24/06	On Hand	FNC01275	
1	Air Magnet Surveyor PRO Software	8/24/06	On Hand	FNC01276	
3	Symbol MC70 1X Battery Cover	8/24/06	Shadwell	FNC01277-1279	Signed for by Arthur Durkin
3	Symbol MC70 Cradle/Charger	8/25/06	Shadwell	FNC01280-1282	Signed for by Arthur Durkin
3	Symbol MC70 PDA	8/29/06	Shadwell	FNC01283-1285	Signed for by Arthur Durkin
3	Li-Ion Extended Battery for Symbol MC70	8/29/06	On Hand	FNC01286-1288	
6	Li-Ion Battery for Symbol MC70	8/29/06	Shadwell	FNC01289-1290,1292-1294,18	Signed for by Arthur Durkin
3	Belt Clip (Rigid Holster) for Symbol MC70	8/29/06	Shadwell	FNC01295-1297	Signed for by Arthur Durkin
2	Zultys 4x5 Power Supply	8/29/06	Shadwell	FNC01298-1299	Signed for by Arthur Durkin
1	Zultys FXS Option Card for MX250	8/29/06	On Hand	FNC01300	
1	Zultys FXS Dongle Cable	8/29/06	On Hand	FNC01301	
1	JK Audio AutoHybrid Telephone Interface	8/29/06	On Hand	FNC01302	
1	CircuitWerkes HC-3 Auto Coupler	8/29/06	On Hand	FNC01303	
2	JonesCAM 480EX Helmet Camera Kit	8/15/06	On Hand	FNC01304-1305	
1	Fog-Tech Anti-Fog Lens Cloth	8/15/06	On Hand	FNC01306	
2	Rechargeable Li-Ion Battery for JonesCAM	8/15/06	On Hand	FNC01307-1308	
2	Glass Lens Protector	8/15/06	On Hand	FNC01309-1310	
2	RCA Female-Female Bullet Adapter	8/15/06	On Hand	FNC01311-1312	
2	RCA Female to BNC Male Adapter	8/15/06	On Hand	FNC01313-1314	

Qty	Product Description	Rec'd	Status (Quantity)	FNC #	Comments
2	JonesCAM 480EX 54 Degree Lens	8/15/06	On Hand	FNC01315-1316	
2	JonesCAM 480EX 39 Degree Lens	8/15/06	On Hand	FNC01317-1318	
2	8 Cell AA Battery Case with 2 Power Cables	8/15/06	On Hand	FNC01319-1320	
1	JonesCAM LX Professional Lipstick Camera	8/15/06	On Hand	FNC01321	
1	JonesCAM 14dB Patch Antenna	8/15/06	On Hand	FNC01322	
1	Axis 2420 IR Illuminator 850 NM	8/15/06	On Hand	FNC01323	
10	Pocket PC Techs 3.5 mm PC Headset to 2.5 mm Adapter	9/5/06	On Hand	FNC01324-1333	
2	Grandstream GXV-3000 SIP Video Phone	9/7/06	On Hand	FNC01334-1335	
3	Clearer Communications Stryker PC Throat Mic/Ear Tube	9/8/06	On Hand	FNC01336-1338	
10	Azden UHF Lav System 100UPR/10BT/EX-503	9/8/06	On Hand	FNC01339-1348	
0	VOID - NO ITEM	N/A	N/A	FNC01349-1351	
1	900 MHz ATV Receiver	9/12/06	On Hand	FNC01352	
0	VOID - NO ITEM	N/A	N/A	FNC01353	
4	Battery Holder 8AA 2x4	9/12/06	On Hand	FNC01354-1357	
4	25 ft BNC to BNC Cable	9/12/06	On Hand	FNC01358-1361	
1	3 ft BNC to BNC Cable	9/12/06	On Hand	FNC01362	
1	Color Micro Vandal Dome Camera	9/12/06	On Hand	FNC01363	
1	2-12mm Varifocal Manual Iris	9/12/06	On Hand	FNC01364	
1	BNC Male to RCA Female Adapter	9/12/06	On Hand	FNC01365	
8	BNC Male to RCA Female Adapter	9/12/06	On Hand	FNC01366-1373	
1	12 VDC 500ma Regulated Power Supply	9/12/06	On Hand	FNC01374	
3	12 VDC 500ma Regulated Power Supply	9/12/06	On Hand	FNC01375-1377	
3	12 VDC 500ma Regulated Power Supply	9/12/06	On Hand	FNC01378-1380	
1	DC 18V to 27V Power Adapter	9/12/06	On Hand	FNC01381	
1	1 Micro 40GB DVR w/ Remote	9/12/06	On Hand	FNC01382	
1	3.5 " TFT Test Monitor	9/12/06	On Hand	FNC01383	
1	Mini 2.4 GHz Transmitter Receiver System	9/12/06	On Hand	FNC01384	
1	Micro Super Low Light High Res Monochrome Video Camera	9/12/06	On Hand	FNC01385	
1	Wireless PC208 Camera	9/12/06	On Hand	FNC01386	
1	Color Pin Hole Micro Video Camera	9/12/06	On Hand	FNC01387	
1	PC221 Color Wide Angle Weatherproof Camera	9/12/06	On Hand	FNC01388	
1	PC222 3B/W Wide Angle Camera	9/12/06	On Hand	FNC01389	
1	PC88WR High Resolution B/W Weatherproof Camera	9/12/06	On Hand	FNC01390	
3	Video Warning Decal	9/12/06	On Hand	FNC01391-1393	
1	Weatherproof Connector tool Kit	9/12/06	On Hand	FNC01394	
1	Single Channel Video Server	9/12/06	On Hand	FNC01395	
1	Single Cable Video TX	9/12/06	On Hand	FNC01396	
2	Y Power Adapter	9/12/06	On Hand	FNC01397-1398	
2	Radio Holder Size #7 Adjustable with Clip	9/13/06	On Hand	FNC01399-1400	
2	Strap Holder Radio	9/13/06	On Hand	FNC01401-1402	
2	2" Equipment Belt	9/13/06	On Hand	FNC01403-1404	
3	Addonics Pocket Series II USB CD/DVD Drive	8/1/06	Shadwell	FNC01405-1407	Signed for by Arthur Durkin
10	Astrodyne SPU12A-105 Wallmount Power Supply	9/15/06	Shadwell(8)	FNC01408-1417	FNC 1408-1415 on Shadwell - Signed for by Arthur Durkin
2	Altec Lansing AHS423 Stereo Behind-The-Neck Headset	9/25/06	On Hand	FNC01418-1419	
2	Plantronics MX-100 2.5mm Headset	9/25/06	On Hand	FNC01420-1421	
2	Plantronics Audio 340	9/25/06	On Hand	FNC01422-1423	
2	Philips SHM1600 Neckband Headset	9/25/06	On Hand	FNC01424-1425	
2	MicroInnovations MM730H Behind-The-Neck Headset	9/25/06	On Hand	FNC01426-1427	
2	VXI TP150 PC Headset	9/25/06	On Hand	FNC01428-1429	
2	AudioTech Compact Headset	9/25/06	On Hand	FNC01430-1431	
1	AudioCodes MP-118 VoIP Gateway	9/25/06	On Hand	FNC01432	
2	Panasonic KX-TCA92 2.5mm Headset	9/25/06	On Hand	FNC01433-1434	
2	Netgear ProSafe 802.11g Firewall/Router	9/25/06	On Hand	FNC01435-1436	
2	Milan 5-Port Ethernet Switch	9/25/06	On Hand	FNC01437-1438	
2	Proxim Orinoco AP-4000 Wireless Access Point	9/25/06	On Hand	FNC01439-1440	
2	Targus Notebook Optical Mouse	9/25/06	On Hand	FNC01441-1442	
1	Targus USB Optical Mouse	9/25/06	On Hand	FNC01443	
10	Black Box 10 Inch Outlet Saver Extension Cord	9/25/06	On Hand	FNC01444-1453	

Qty	Product Description	Rec'd	Status (Quantity)	FNC #	Comments
1	Polycom Soundpoint IP430 Phone	9/25/06	On Hand	FNC01454	
1	Polycom Soundpoint IP301 Phone	9/25/06	On Hand	FNC01455	
1	Asterisk Business Edition 40-User VoIP Software	9/25/06	On Hand	FNC01456	
2	Milan 8-Port Ethernet Switch	9/25/06	On Hand	FNC01457-1458	
6	Panasonic KX-TCA92 2.5mm Headset	9/25/06	Shadwell (4)	FNC01459-1464	FNC1461-1464 (4) on Shadwell - Signed for by Arthur Durkin
6	Plantronics MX-100 2.5mm Headset	9/25/06	Shadwell (4)	FNC01465-1470	FNC1467-1470 (4) on Shadwell - Signed for by Arthur Durkin
8	Shure QuietSpot Boom 2.5mm Headset	9/25/06	Shadwell (4)	FNC01471-1478	FNC1471-1474 (4) on Shadwell - Signed for by Arthur Durkin
10	3.5mm Stereo Male to 2X 3.5mm Stereo Female	9/25/06	On Hand	FNC01479-1488	
10	3.5mm Mono Male to 3.5mm Stereo Female	9/25/06	On Hand	FNC01489-1498	
10	2.5mm Stereo Plug to 3.5mm Stereo Female	9/25/06	On Hand	FNC01499-1508	
10	3.5mm Stereo Male to 3.5mm Mono Female	9/25/06	On Hand	FNC01509-1518	
1	7.5" 100-Pack Black Cable Tie	9/25/06	On Hand	FNC01519	
10	2.5mm Mono Male to 3.5mm Stereo Female	9/25/06	On Hand	FNC01520-1529	
2	6 inch Velcro cable straps Black 12-Pack	9/25/06	On Hand	FNC01530-1531	
1	11.5inch Black Cable Ties 100-Pack	9/25/06	On Hand	FNC01532	
1	11inch Velcro Straps Multi-Color 12-Pack	9/25/06	Shadwell(4)	FNC01533	Signed for by Arthur Durkin
8	Connector 5-15 NEMA - 4A254	9/25/06	On Hand	FNC01534-1541	
20	Plug Valise 5-15 NEMA - 4A253	9/25/06	On Hand	FNC01542-1561	
5	30-foot Cord Reel Auto Retract (Yellow) - 1A136	9/25/06	Shadwell(4)	FNC01562-1566	FNC1562,1564,1565,1566 (4) on Shadwell - Signed for by Arthu
6	Extension Cord 10 foot - 3EA97	9/25/06	On Hand	FNC01567-1572	
4	Extension Cord 3-10 foot - 3AY48	9/25/06	On Hand	FNC01573-1576	
6	4-Outlet Power Strip w/ Switch - 3X732	9/25/06	On Hand	FNC01577-1582	
6	5-Outlet Electric Outlet Strip - 6X952	9/25/06	Shadwell(4)	FNC01583-1588	Integrated into CommCases - FNC1583-1586 on Shadwell - Sign Arthur Durkin
6	Power Center 6 Outlets - 5HN14	9/25/06	On Hand	FNC01589-1594	
2	Outlet Strip 15A 120V - 2MY43	9/25/06	On Hand	FNC01595-1596	
2	Power Center 6 Outlets - 5HN49	9/25/06	On Hand	FNC01597-1598	
2	6-Outlet Power Strip with Switch - 3X733	9/25/06	On Hand	FNC01599-1600	
2	Power Center 6 Outlets - 5HN15	9/25/06	On Hand	FNC01601-1602	
2	10-Outlet Electric Power Strip w/ Switch - 1A946	9/25/06	On Hand	FNC01603-1604	
7	Padded Shoulder Strap - 2ZY18	9/25/06	Shadwell(4)	FNC01605-1611	FNC 1605-1608 on Shadwell - Signed for by Arthur Durkin
2	Outlet Strip 15A 120V - 2MY54	9/25/06	On Hand	FNC01612-1613	
1	Hook & Loop 1" x 4.9 Yd Black Adhesive	9/25/06	On Hand	FNC01614	
48	9-Volt Alkaline Batteries	9/25/06	Shadwell	FNC01615	Signed for by Arthur Durkin
10	DC Telephone Hybrid Transformer	9/25/06	On Hand	FNC01616-1625	
20	Alkaline C Batteries	9/25/06	Consumed	FNC01626	
10	Box NEMA 4 Aluminum 3.54 x 1.42 NAT	9/25/06	On Hand	FNC01627-1636	
10	Conn Plug Stereo 2.5mm w/ cover	9/25/06	On Hand	FNC01637-1646	
10	Conn 3.5mm Male Stereo Plug	9/25/06	On Hand	FNC01647-1656	
10	Ferrite H/F EMI Clamp-On 5.30mm	9/25/06	On Hand	FNC01657-1666	
10	Ferrite Cylinder Clamp-On White	9/25/06	On Hand	FNC01667-1676	
6	theBoom v4 Headset	9/25/06	On Hand	FNC01677-1682	
3	theBoom with eartube	9/25/06	On Hand	FNC01683-1685	
10	Computer PC Jack	9/25/06	On Hand	FNC01686-1695	
5	theBoom v4 ear wrap	9/25/06	On Hand	FNC01696-1700	
6	Speaker Gel v4	9/25/06	On Hand	FNC01701-1706	
10	Standard 2.5mm Headset Jack	9/25/06	On Hand	FNC01707-1716	
2	20-foot Retractable Power Cord Reel (Blue)	9/26/06	On Hand	FNC01717-1718	
10	Toggle Switch DPDT 5A	9/25/06	On Hand	FNC01719-1728	
7	Box 2.4 X .85 X .93 With Clip (Black Plastic)	9/25/06	On Hand	FNC01729-1735	
10	Cable Assy R/A 2.5mm Mono 6-foot	9/25/06	On Hand	FNC01736-1745	
10	Cable Assy R/A 3.5mm Mono 6-foot	9/25/06	On Hand	FNC01746-1755	
10	Cable Assy R/A 2.5mm Stereo 6-foot	9/25/06	On Hand	FNC01756-1765	
10	Cable Assy R/A 3.5mm Stereo 6-foot	9/25/06	On Hand	FNC01766-1775	
10	Cable Grip Black 5.5-12mm	9/25/06	On Hand	FNC01776-1785	
1	Crimper Telephone Plug RJ11/RJ45	9/25/06	On Hand	FNC01786	
20	Vinyl Hole Grommet 5/32" ID	9/25/06	On Hand	FNC01787-1806	
20	Vinyl Hole Grommet 1/8" ID	9/25/06	On Hand	FNC01807-1826	

Qty	Product Description	Rec'd	Status (Quantity)	FNC #	Comments
20	Vinyl Hole Grommet 7/32" ID	9/25/06	On Hand	FNC1827-1846	
10	Cord 18AWG 3COND 118" Black SVT	9/25/06	On Hand	FNC01847-1856	
6	Black Box 4-Outlet Power Strip w Switch - PS165A	9/26/06	On Hand	FNC01857-1862	
1	Snively - Intermec Mounting Bracket	9/27/06	On Hand	FNC01863	
3	Snively Intermec Coax *RP/SMA-RP/N 256" FOR IF5	9/27/06	On Hand	FNC01864-1866	
1	Snively Intermec 915*KSD, 9dBi Antenna	9/27/06	On Hand	FNC01867	
1	Snively Intermec *86x CIR POL 8dBi Antenna	9/27/06	On Hand	FNC01868	
1	Snively Intermec IF5 Reader: FCC 802.11g, 915 MHz	9/27/06	On Hand	FNC01869	
6	Earmark Throat Microphone	9/27/06	Shadwell(4)	FNC01870-1875	FNC01870-1873 on Shadwell - Signed for by Arthur Durkin
1	Earmark SAC (Suface Adhering Microphone)	9/27/06	On Hand	FNC01876	
1	Symbol MC70 1X Battery Cover	9/27/06	Shadwell	FNC01877	Signed for by Arthur Durkin
1	Symbol MC70 Cradle/Charger	9/27/06	Shadwell	FNC01878	Signed for by Arthur Durkin
1	Symbol MC70 PDA	9/27/06	Shadwell	FNC01879	Signed for by Arthur Durkin
1	Li-Ion Extended Battery for Symbol MC70	9/27/06	On Hand	FNC01880	
1	Belt Clip (Rigid Holster) for Symbol MC70	9/27/06	On Hand	FNC01881	
1	Li-Ion Extended Battery for Symbol MC70	10/2/06	On Hand	FNC01882	
1	Li-Ion Battery for Symbol MC70	10/3/06	Shadwell	FNC01291	
3	theBoom with eartube	10/3/06	On Hand	FNC01884-1886	
6	Pryme Deluxe Ear Phone EH-189XC	10/6/06	Shadwell(4)	FNC01887-1892	FNC01887-1890 on Shadwell - Signed for by Arthur Durkin
6	Pryme Ear Buds EH-1099X	10/9/06	On Hand	FNC01893-1898	
5	ParMarLow Throat Microphone	10/10/06	On Hand	FNC01899-1903	
4	Storm Case	10/11/06	Shadwell	FNC01904-1907	Signed for by Arthur Durkin
1	Intermec 915 7 dBi Circular Polarized Antenna	10/11/06	On Hand	FNC01908	
3	Box 2.4 X .85 X .93 With Clip (Black Plastic)	10/10/06	On Hand	FNC01909-1911	
20	Cat 5e Shielded Patch Cable 1-foot	10/13/06	Shadwell(4)	FNC01909-1928	FNC1909-1912 in CommCases on Shadwell - Signed for by Arth
15	Cat 5e Shielded Patch Cable 3-foot	10/13/06	On Hand	FNC01929-1943	
3	Cat 5e Shielded Patch Cable 5-foot (has unshielded conns)	10/13/06	On Hand	FNC01944-1946	
3	Cat 5e Shielded Patch Cable 7-foot	10/13/06	On Hand	FNC01947-1949	
2	Cat 5e Shielded Patch Cable 10-foot	10/13/06	On Hand	FNC01950-1951	
1	Cat 5e Shielded Patch Cable 25-foot	10/13/06	On Hand	FNC01952	
1	Cat 5e Shielded Patch Cable 50-foot	10/13/06	On Hand	FNC01953	
1	Cushcraft DirectLink Pipe Mount Kit	5/6/06	On Hand	FNC01954	
2	Cat 5e Shielded Patch Cable 14-foot	10/18/06	On Hand	FNC01955-1956	
10	Radio Holder Size #7 Adjustable with Clip	9/28/06	On Hand	FNC01957-1966	
10	Strap Holder Radio	9/28/06	On Hand	FNC01967-1976	
10	2" Equipment Belt	9/28/06	On Hand	FNC01977-1986	
1	Outlet Strip 15A 120V - 2MY54	10/2/06	On Hand	FNC01987	

APPENDIX D - ACRONYMS

AC ..... Alternating Current

ADC ..... Advanced Damage Countermeasures

AES ..... Advanced Encryption Standard

AFT ..... Automated File Transceiver

ANSI ..... American National Standard Institute

AP ..... Access Point

ATA ..... Analog telephone adapters

BPL ..... Broadband over Power Line

COTS ..... Commercial Off-The-Shelf

CTC ..... Custody Transfer Cards

dB ..... Decibel

dBm ..... Decibel referenced to 1 milliwatt

DC ..... Damage Control

DC-ARM ..... Automation for Reduced Manning

DCC ..... Damage Control Central

DCOC ..... Damage Control Operational Concepts

DHCP ..... Dynamic Host Configuration Protocol

EMI ..... Electro-Magnetic Interference

FIPS ..... Federal Information Processing Standards

FNC-CRIDCC ..... Future Naval Capabilities—Crew Reductions through Improved Damage Control

FXS ..... Foreign Exchange Station

GUI ..... Graphic User Interface

IBPLC ..... In-Building PLC

IP ..... Internet Protocol

IPT ..... Integrated Program Team

LAN ..... Local Area Network

LCD ..... Liquid Crystal Display

LED ..... Light Emitting Device

LRK ..... L. Robert Kimball & Associates

Mbps ..... Megabits per second

MOC ..... Microphone Output Control

MOS ..... Mean Opinion Score

MTS ..... MTS Technologies, Inc.

NAT ..... Network Address Translation

NRL ..... Naval Research Laboratory

OFDM ..... Orthogonal Frequency Division Multiplexing

ONR ..... Office of Naval Research

OSL ..... On-Scene Leader

PBX ..... Private Branch Exchange

PC ..... Personal Computer

PDA ..... Personal Digital Assistant

PLC ..... Power Line Communications

PM ..... Program Manger

PPE ..... Personal Protective Equipment

PSD ..... Power Spectral Density

PSTN ..... Public Switched Telephone Network

R&D ..... Research & Development

RDT&E ..... Research, Development, Test and Evaluation

RF ..... Radio Frequency

RL ..... Repair Locker

RRT ..... Rapid Response Team

SCBA ..... Self-Contained Breathing Apparatus

SIP ..... Session Initiation Protocol

SPP ..... Sound-Powered Phone

TKIP ..... Temporal Key Integrity Protocol

UTA ..... Universal Telephony Adapter

VAB ..... Virginia Beach,VA

VAC ..... Volts Alternating Current

VO ..... Voice Over

VoIP ..... Voice/Data over Internet Protocol

VPN ..... Virtual Private Network

VQT ..... Voice Quality Test

WEP ..... Wired Equivalent Privacy

WiFI ..... Wide Fidelity

WLAN ..... Wireless Local Area Network

WPA ..... WiFi Protected Access

WPA2 ..... WiFi Protected Access 2